Bellcore

GENERIC REQUIREMENTS
GR–2837–CORE
ISSUE 4, FEBRUARY 1998

Comments Requested
(See Preface)

ATM Virtual Path Ring Functionality in SONET - Generic Criteria

(A Module of TSGR, FR–440)

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This document, GR–2837–CORE, Issue 4, February 1998, replaces:

GR–2837–CORE, Issue 3, October 1996.

For ordering information, see the References section of this document.

Project funding year: 1997, 1998.

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TRANSPORT SYSTEMS GENERIC REQUIREMENTS (TSGR)

FR-440

Introducing the 1998 Edition

The *Transport Systems Generic Requirements (TSGR)* provides Bellcore's view of proposed generic requirements applicable to a wide variety of digital transport systems that possess the same functionalities independent of the environment in which the transport is deployed and the services it supports. These transport systems provide the means to transmit information between designated interfaces in a communications network. They consist of hardware, software, and media that combine, process, and transmit signals used to support telecommunications services. The TSGR also serves as a guide for analyzing new digital transmission systems and helps to eliminate possible redundancy and inconsistency in transport requirements. The TSGR contents table lists all documents in the 1998 Edition.

Note:

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FR-440, Transport System Generic Requirements (TSGR) – 1998 Edition

Vol	Section	Module
1	Common Criteria	Common Requirements, GR-499
		NEBS, GR-63
		Alarm Indication Signal, TR-TSY-000191
		Supplier-Provided Documentation, GR-454
		Supplier-Provided Training, GR-839
		Supplier Support, TR-NWT-000840
		EMC and Electrical Safety, GR-1089
		Assuring Corrosion Resistance of Outside Equipment, GR-2836
2	DLC System, UDC, and Basic Exchange Radio Systems	Digital Loop Carrier Systems, TR-NWT-000057
		Universal Digital Channel (UDC), TR-TSY-000398
		Basic Exchange Radio Systems, TR-NWT-000911
3	IDLC System	IDLC System, GR-303
4	ISDN Transport, Interface, and Related Requirements	ISDN Basic Access DSL, TR-NWT-000393
		ISDN Basic Access Transport, TR-NWT-000397
		ISDN PRA Transport, TR-TSY-000754
5	Digital Radio Systems	Microwave Digital Radio, TR-TSY-000752
6	SONET Common Criteria	SONET Transport Systems: Common Generic Criteria, GR-253
		SONET OC-192 Criteria, GR-1377
		SONET Private Line Service Interface Criteria, GR-1365
		SONET Inter-Carrier Interface Criteria, GR-1374
7	SONET Network Element Criteria	SONET Add/Drop Multiplex, TR-NWT-000496
		Wideband and Broadband Digital Cross-Connect, TR-NWT-000233
		SONET Digital Switch Trunk Interface, TR-TSY-000782
		SONET RGTR Equipment Criteria, TR-NWT-000917
		SONET Dual-Fed UPSR Criteria, GR-1400
		SONET BLSR Criteria, GR-1230
		Self-Healing Ring-Functionality in Digital Cross-Connect Systems, GR-1375
		ATM Virtual Path Ring Functionality in SONET–Generic Criteria, GR-2837
		SONET Digital Cross-Connect Systems with ATM Functionality–Generic Criteria, GR-2891

ATM Virtual Path Ring Functionality in SONET - Generic Criteria

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Preface

This Preface contains important information about Bellcore's GR process in general, as well as important information about this document.

Bellcore's GR Process

Generic Requirements documents (GRs) provide Bellcore's view of proposed generic criteria for telecommunications equipment, systems, or services, and involve a wide variety of factors, including interoperability, network integrity, funding participant expressed needs, and other input.

Bellcore's GR process implements Telecommunications Act of 1996 directives relative to the development of industry-wide generic requirements relating to telecommunications equipment, including integral software and customer premises equipment. Pursuant to that Act, Bellcore invites members of the industry to fund and participate in the development process for such GRs. Invitations to fund and participate are issued monthly in the *Bellcore Digest of Technical Information*, and posted on Bellcore's web site at *http://www.bellcore.com/DIGEST*.

At the conclusion of the GR development process, Bellcore publishes the GR, which is available by subscription. The subscription price entitles the purchaser to receive that issue of the GR (GR-CORE) along with any Issues List Report (GR-ILR) and Revisions, if any are released under that GR project. ILRs contain any technical issues that arise during GR development that Bellcore and the funding participants would like further industry interaction on. The ILR may present issues for discussion, with or without proposed resolutions, and may describe proposed resolutions that lead to changes to the GR. Significant changes or additional material may be released as a Revision to the GR-CORE.

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About GR–2837–CORE

A. Funders of GR–2837–CORE, Issue 4, are:

ADC Telecommunications

BellSouth

Pacific Bell.

B. Relative Maturity Level

This document is the fourth issue of GR–2837–CORE, generic requirements for ATM Virtual Path ring functionality in SONET. This document should not be considered mature in that there are criteria for which only a limited set of requirements are given, based on preliminary agreements within the various national and international standards bodies. This issue replaces GR–2837–CORE, Issue 3.

C. GR–2837–CORE Plans

Bellcore is tentatively planning a revision or reissue of this GR in 1998 that will reflect the continuing work both within Bellcore and in national and international standards bodies.

To Submit Comments

When submitting comments, please include the GR document number, and cite any pertinent section and requirement number. In responding to an ILR, please identify the pertinent Issue ID number. Please provide the name and address of the contact person in your company for further discussion.

Comments should be submitted by May 15, 1998.

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1. Introduction

This Generic Requirements document (GR) provides Bellcore's view of proposed generic functional criteria for incorporating Asynchronous Transfer Mode (ATM) Virtual Path (VP) functionality into Synchronous Optical Network (SONET) rings. This functionality can be incorporated into existing SONET Ring Add-Drop Multiplexers (ADMs), or into pure ATM Ring ADMs that use SONET as physical layer medium. SONET Ring ADMs with the added ATM VP functionality and pure ATM Ring ADMs are capable of processing ATM cells at the ATM VP level. SONET Ring ADMs with ATM VP functionality are referred to as Hybrid SONET/ATM ADMs, or simply as Hybrid ADMs.

This GR presents requirements for rings that can provide both SONET and ATM level transport multiplexing and protection switching, and for rings that provide only ATM level transport and protection switching. The requirements meet the needs for ring equipment which can efficiently carry a mixture of Synchronous Transfer Mode (STM) and ATM traffic by using STM multiplexing and existing SONET protection mechanisms for the STM traffic and ATM multiplexing and SONET and/or new ATM protection mechanisms for the ATM traffic. The requirements can also be used to support ring equipment that carries only ATM traffic and uses ATM multiplexing and ATM protection switching. Thus, the GR can support environments where a mix of ATM and STM traffic needs to be supported as well as environments where only ATM traffic needs to be supported. Requirements for pure SONET applications (e.g., SONET UPSR, SONET BLSR) are addressed in other Bellcore GRs listed below.

The criteria in this document are subject to change for various reasons. Service providers may alter generic criteria to meet their individual needs, and to complement their short-term and long-term deployment strategies. Since each service provider may have needs and requirements differing from the generic criteria set forth in this document, suppliers should communicate directly with each service provider or other network operator to ascertain that company's individual requirements.

1.1 Purpose and Scope

The criteria contained herein are intended to advise the telecommunications industry of Bellcore's view of proposed generic requirements in support of ATM VP ring functionality in SONET, and to reflect recent work in the various committees and subcommittees of standards organizations such as the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) and ANSI-accredited Committee T1.

This GR is not a stand-alone document; it is intended to be used with other Technical Advisories (TAs), Technical References (TRs), and GRs. This GR focuses on criteria and issues specific to SONET Ring transport systems and should be used in conjunction with the following Bellcore documents. Note that the new GR–2980–CORE is one of the major supporting documents.

- SONET:
  - TR-NWT-000496, *SONET Add-Drop Multiplex Equipment (SONET ADM) Generic Criteria.*
  - GR-253-CORE, *SONET Transport Systems: Common Generic Criteria.*
  - GR-1230-CORE, *SONET Bidirectional Line-Switched Ring Equipment Generic Criteria.*
  - GR-1400-CORE, *SONET Dual-Fed, Unidirectional Path Switched Ring (UPSR) Equipment Generic Criteria.*
- Hybrid SONET/ATM (see Section 2 for a discussion of Hybrid equipment):
  - GR-2891-CORE, *SONET Digital Cross-Connect Systems with ATM Functionality – Generic Criteria.*
  - GR-2955-CORE, *Operations Functional Requirements for Integrated SONET/ ATM Element Management Systems (EMS).*
- ATM:
  - GR-1110-CORE, *Broadband Switching System (BSS) Generic Requirements.*
  - GR-1113-CORE, *Asynchronous Transfer Mode (ATM) and ATM Adaptation Layer (AAL) Protocols Generic Requirements.*
  - GR-1115-CORE, *BISDN Inter/Intra-Carrier Interface (B-ICI) Generic Requirements.*
  - GR-1248-CORE, *Generic Requirements for Operations of ATM Network Elements.*
  - GR-2842-CORE, *ATM Service Access Multiplexer (SAM) Generic Requirements.*
  - GR-2980-CORE, *Generic Criteria for ATM Layer Protection Switching Mechanism.*
  - TR-NWT-01112, *Broadband ISDN User to Network Interface and Network Node Interface Physical Layer Generic Criteria.*
- TMN:
  - GR-2869-CORE, *Generic Requirements for Operations Based on the Telecommunications Management Network (TMN) Architecture.*

1.2 Target Audience

The criteria contained in this document are intended to advise the telecommunications industry of Bellcore's view of a new network element and proposed requirements for the

latter. In a narrower sense, the information is targeted to service providers' broadband network and operations planners and implementers, as well as suppliers of SONET ATM ring equipment.

1.3 Structure and Use of This Document

The remainder of this GR is organized as follows:

- Section 2 discusses SONET, ATM, and Hybrid terminology, network elements, and networks.
- Section 3 describes potential ring network applications for SONET ATM network elements.
- Section 4 covers the functional model and associated requirements for ATM Virtual Path functionality in SONET rings.
- Section 5 reviews the operations functionality and provides requirements covering the operations architecture, operations functions, and network traffic management, and describes how these functions are supported by operations communications, operations flows, and operations interfaces.
- Detailed references and ordering information appear in the References section.
- Acronyms used throughout the document are listed in the Acronyms section.
- A summary of all requirements appears in the Requirement-Object List.
- An index of all requirements ordered by absolute number, relating to local number and page number, appears in the Requirement-Object Index.

1.4 Major Changes from Issue 3

This section lists the major changes since Issue 3 of GR–2837–CORE.

- Section 2 has been expanded and introduces a new and more consistent terminology. The other sections have been aligned to reflect the new terminology. Further, overviews on ATM protection switching and ring interconnection have been added.
- Section 3 is a new section, presenting potential network applications. Material from the previous Sections 3 and 4 is now in Sections 4 and 5, respectively.
- Section 4 has been expanded with respect to functional models and requirements.
- ATM layer protection switching has been aligned with the preliminary agreements reached in national and international standards bodies.

- Section 5 has been expanded to include detailed descriptions of functions and procedures as well as requirements for network traffic management.

1.5 Requirements Terminology

The following requirements terminology is used throughout this document:

- **Requirement** — Feature or function that, in Bellcore's view, is *necessary* to satisfy the needs of a BCC. Failure to meet a requirement may cause application restrictions, result in improper functioning of the product, or hinder operations. A Requirement contains the words *shall* or *must* and is flagged by the letter "**R**."
- **Conditional Requirement** — Feature or function that, in Bellcore's view, is *necessary in specific BCC applications*. If a BCC identifies a Conditional Requirement as necessary, it shall be treated as a requirement for the application(s). Conditions that may cause the Conditional Requirement to apply include, but are not limited to, certain BCC application environments, elements, or other requirements, etc. A Conditional Requirement is flagged by the letters "**CR**."
- **Objective** — Feature or function that, in Bellcore's view, is *desirable* and may be required by a BCC. An Objective represents a goal to be achieved. An Objective may be reclassified as a Requirement at a specified date. An objective is flagged by the letter "**O**" and includes the words *it is desirable* or *it is an objective*.
- **Conditional Objective** — Feature or function that, in Bellcore's view, is *desirable in specific BCC applications* and may be required by a BCC. It represents a goal to be achieved in the specified Condition(s). If a BCC identifies a Conditional Objective as necessary, it shall be treated as a requirement for the application(s). A Conditional Objective is flagged by the letters "**CO**."
- **Condition** — The circumstances that, in Bellcore's view, will cause a Conditional Requirement or Conditional Objective to apply. A Condition is flagged by the letters "**Cn**."

1.6 Requirement Labeling Conventions

As part of Bellcore's new GR Process, proposed requirements and objectives are labeled using conventions that are explained in the following two sections.

1.6.1 Numbering of Requirement and Related Objects

Each Requirement, Objective, Condition, Conditional Requirement, and Conditional Objective object is identified by both a local and an absolute number. The local number

consists of the object's document section number and its sequence number in the section (e.g., **R3-1** is the first Requirement in Section 3). The local number appears in the margin to the left of the Requirement. A Requirement object's local number may change in subsequent issues of a document if other Requirements are added to the section or deleted.

The absolute number is a permanently assigned number that will remain for the life of the Requirement; it will not change with new issues of the document. The absolute number is presented in brackets (e.g., **[2]**) at the beginning of the requirement text.

Neither the local nor the absolute number of a Conditional Requirement or Conditional Objective depends on the number of the related Condition(s). If there is any ambiguity about which Conditions apply, the specific Condition(s) will be referred to by number in the text of the Conditional Requirement or Conditional Objective.

References to Requirements, Objectives, or Conditions published in other Generic Requirements documents will include both the document number and the Requirement object's absolute number. For example, **R2345-12** refers to Requirement **[12]** in GR–2345.

1.6.2 Requirement, Conditional Requirement, and Objective Object Identification

A Requirement object may have numerous elements (paragraphs, lists, tables, equations, etc.). To aid the reader in identifying each part of the requirement, an ellipsis character (...) appears in the margin to the left of all elements of the Requirement.

2. Background and Terminology

This section begins with a general discussion of ATM transport over SONET ATM networks, and then presents a terminology for SONET, ATM, and Hybrid SONET/ATM entities, together with a set of definitions. This terminology is slightly modified from the one used in the previous issue in order to provide more consistency between the three types of entities. The section then moves into an overview of SONET, ATM, and Hybrid SONET/ATM network elements (NEs). Following is a more detailed discussion of the efficiency of ATM transport in Hybrid SONET/ATM rings, and overviews on ATM protection switching and ring interconnection.

2.1 SONET ATM Transport Networks

One can distinguish between three basic methods for transporting ATM and STM traffic over SONET physical layer facilities. Figure 2-1 shows the three methods for combining ATM and STM traffic over a single transport network.

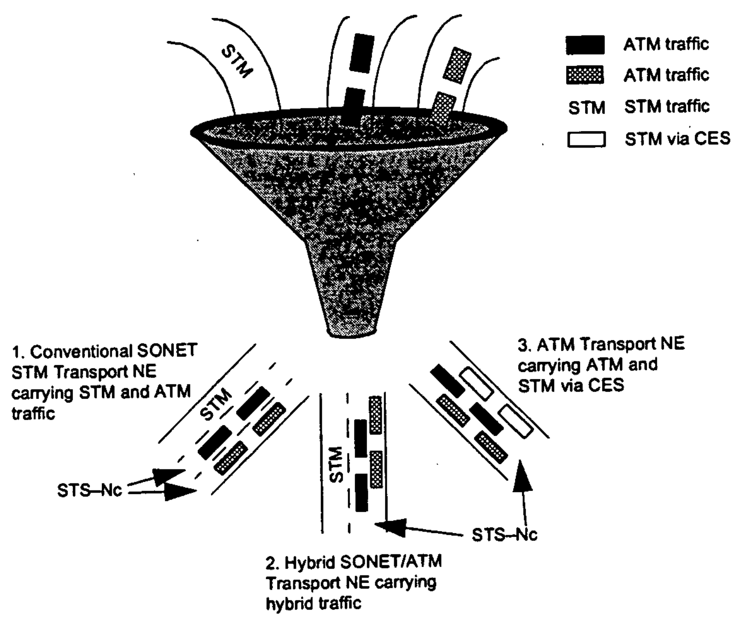


Figure 2-1. Three Methods of Combining ATM and STM Traffic

The first method uses conventional SONET transport NEs and combines the ATM and STM traffic onto the same SONET facility, but over different STS-1s or STS–Ncs. ATM cells are mapped to SONET payloads (e.g., into an STS-1 or STS–Nc Synchronous Payload Envelope) but the SONET transport NEs only process at the SONET layer; they do not

process at the ATM layer. Each ATM cell stream from the customer requires its own STS-1 or STS–Nc with this method, even if it uses only a small fraction of the bandwidth. Figure 2-2 shows an example network using conventional ATM and SONET NEs. ATM edge and hub switches can be used for ATM cell switching, and SONET ring ADMs and DCSs can be used for transport. The SONET transport network provides transparent transport of ATM cells from the customer ATM CPE to the ATM switch and back to the customer ATM CPE.

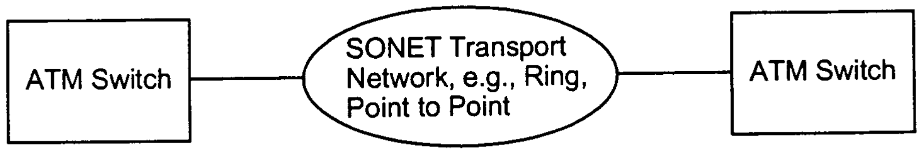


Figure 2-2. Conventional ATM Switching and SONET Transport Network

The second method for combining ATM and STM traffic over a single transport network uses Hybrid SONET/ATM NEs and also combines the ATM and STM traffic onto the same SONET facility over different STS–Ncs. However, Hybrid SONET/ATM NEs are SONET NEs with ATM cell processing capability, allowing the ATM traffic from different sources to be aggregated and carried in a single STS-1 or STS–Nc, resulting in more efficient transport. The term *Hybrid SONET/ATM*, or *Hybrid* for short, is used to refer to networks, equipment, and traffic. Figure 2-3 shows an example of a Hybrid SONET/ATM network using Hybrid SONET/ATM NEs. An ATM Service Access Multiplexer (SAM) is used at the edge of the public ATM network to provide ATM interfaces and adaptation for customer services. The Hybrid Ring is a SONET based ring (either UPSR or BLSR) in which the ADMs have ATM cell processing capabilities. This allows sharing of a SONET payload for ATM traffic among several ring nodes. The Hybrid DCS provides ATM VP level cross-connection, grooming and management.

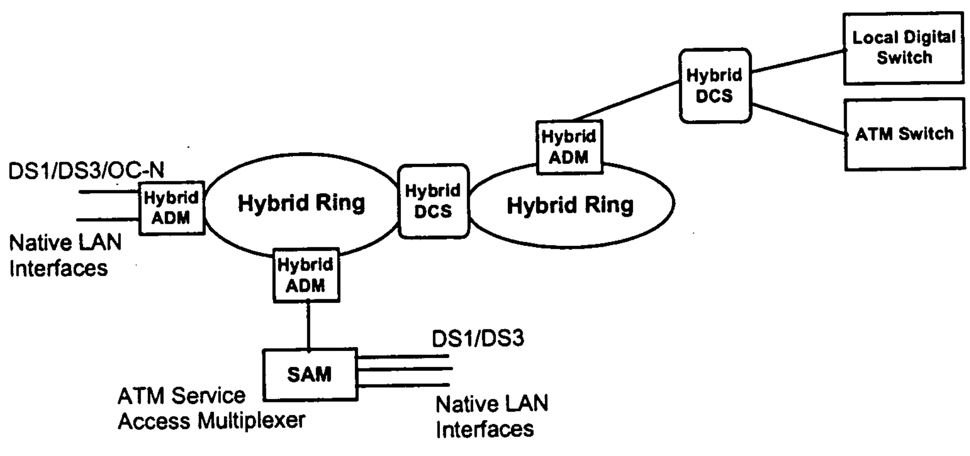


Figure 2-3. Hybrid SONET/ATM NEs in an Example Network

The third method for transporting ATM and STM traffic over a single transport network uses pure ATM NEs that convert the STM traffic into ATM cells (via ATM Circuit Emulation Service [CES]) and carry all STM and ATM traffic as ATM cells in a single STS–Nc. The term *pure ATM,* or *ATM* for short, is used to refer to networks, equipment, and traffic. Figure 2-4 shows an example of a pure ATM network using pure ATM NEs. It is similar to the above Hybrid network, but STM signals are carried through the two ATM Rings via circuit emulation and are restored to STM before they continue their path through the Hybrid DCS to the Local Digital Switch.

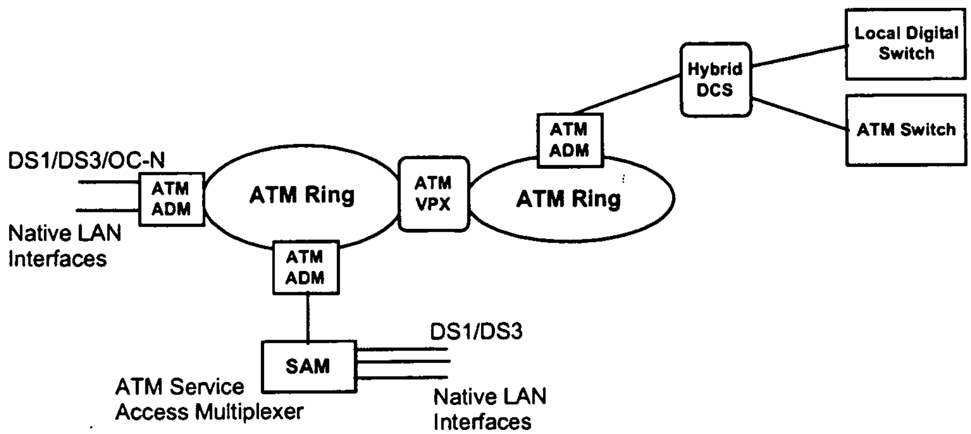


Figure 2-4. Pure ATM NEs in an Example Network

Figure 2-5 shows the transport protocol layer structure that is used with each of these three methods for transporting ATM and STM traffic. STM Transport corresponds to method 1 in Figure 2-1 (with conventional SONET NEs), where the ATM cells are completely transparent to the SONET NEs. Hybrid Transport corresponds to method 2 in Figure 2-1 (with Hybrid SONET/ATM NEs), where the NEs have visibility into both the SONET signal for STM traffic and the ATM cells for ATM traffic. ATM Transport corresponds to method 3 in Figure 2-1 (with ATM NEs), where the NEs have visibility of the ATM cells only; these ATM cells carry both ATM traffic and STM traffic converted into ATM via CES. Note that with all three methods, SONET is the underlying transport mechanism.

As seen in these figures, there are several ways that ATM and STM services can be transported. Two of them provide efficient ATM transport, each one optimized for certain applications as follows.

Hybrid transport NEs are well suited for use throughout an evolution from STM services to STM and ATM services and finally to all ATM services. Hybrid transport NEs are capable of handling the full range from 100% STM (0% ATM) to x% STM (100-x% ATM) to 0% STM (100% ATM). Thus, Hybrid transport NEs will assist service providers in making a gradual transition from an embedded base of existing SONET networks to all ATM networks, with efficient ATM transport throughout.

Pure ATM transport NEs are well suited for new installations of networks carrying mainly ATM traffic and providing a variety of broadband services including data, video, and voice (the latter through CES). Thus, pure ATM transport NEs will enable service providers to enter new markets for broadband services where there is no embedded base of existing SONET networks.

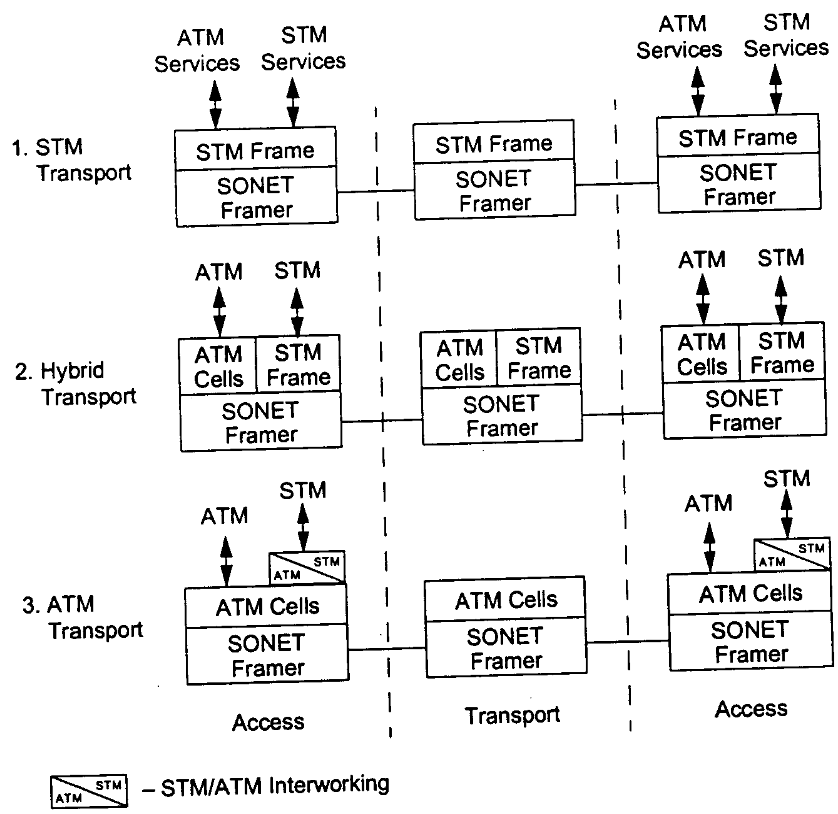


Figure 2-5. Layer Structure of STM and ATM Transport Methods

2.2 Terminology and Definitions

2.2.1 Summary

This section summarizes the terms and definitions used in this GR in the form of a glossary. The terminology for SONET, ATM, and Hybrid SONET/ATM entities is slightly modified from the one used in the previous issue of this GR in order to provide more consistency

between the three types of entities. The terms are used throughout this document and are explained in more detail in the following sections.

Transport Networks

SONET Network (short for pure SONET Network):

> A network that carries only conventional SONET STM signals. Such a network contains only pure SONET NEs. The network may also transparently transport STM signals (i.e., DSn and SONET STS-N) that contain ATM cells as payload, referred to as conventional ATM on SONET. However, the SONET network does not have visibility to the ATM layer.

ATM Network (short for pure ATM Network):

> A network that carries only ATM cells on SONET STS-1s or STS-Ncs, or on a non-SONET physical layer, for example DS3. Such a network contains only pure ATM NEs. The network may also transparently transport ATM cells that contain STM signals (i.e., DSn and SONET STS-N) in the form of ATM circuit emulation.

Hybrid Network (short for Hybrid SONET/ATM Network):

> A network that carries SONET STM signals on some of the STS-Ns and ATM cells on other STS-Ns (STS-1s or STS-Ncs). Such a network contains Hybrid NEs, and in addition it may also contain pure SONET NEs and pure ATM NEs. The Hybrid and ATM NEs provide efficient ATM access to the network.

Transport Network Elements - Generic

SONET NE (short for pure SONET Transport Network Element):

> An NE that processes all traffic at the STM layer (time slot processing/routing and time division multiplexing). It is also able to process or transparently pass STM signals (i.e., DSn and SONET STS-N) that contain ATM cells as payload, referred to as conventional ATM on SONET.

ATM NE (short for pure ATM Transport Network Element):

> An NE that processes all traffic at the ATM layer (ATM cell processing/routing and ATM cell multiplexing). It may have SONET STS-N or STS-Nc or other physical layer interfaces for the transport of ATM cells. At such an interface, the SONET or other physical layer is always terminated and the ATM cells are separated from the payload. The ATM NE may also be able to process or transparently pass ATM cells that contain STM signals (i.e., DSn and SONET STS-N) in the form of ATM circuit emulation.

Hybrid NE (short for Hybrid SONET/ATM Transport Network Element):

An NE that can process traffic at the STM layer (time slot processing/routing and time division multiplexing) as well as the ATM layer (ATM cell processing/routing and ATM cell multiplexing). This means it can perform the functions of a SONET NE as well as an ATM NE.

Transport Network Elements - Specific

SONET ADM (short for pure SONET Add/Drop Multiplexer):

A SONET NE with STM (STS or VT level) add/drop functionality. The SONET ADM may be suitable for linear and/or ring applications. A SONET Ring ADM may be configured for use in a 2-fiber UPSR, or a 2-fiber or 4-fiber BLSR, each with STM layer self-healing characteristics.

SONET ATM VP ADM:

An NE with a SONET physical layer that may either process ATM traffic exclusively (**Pure ATM ADM**, see below) or that may be able to process a combination of ATM and STM traffic (**Hybrid ADM**, see below).

Pure ATM ADM (short for pure ATM Add/Drop Multiplexer):

An ATM NE with ATM VP add/drop functionality. The ATM ADM may be suitable for linear and/or ring applications. An ATM Ring ADM may be configured for use in an ATM UVPSR (see below) or an ATM BVPSR (see below). Such ring configurations do not have the STM layer self-healing characteristics found in SONET rings. ATM layer protection will take its place.

Hybrid ADM (short for Hybrid SONET/ATM Add/Drop Multiplexer):

A Hybrid NE with STM (STS or VT level) and ATM VP add/drop functionality. The Hybrid ADM may be suitable for linear and/or ring applications. A Hybrid Ring ADM may be configured for use in a 2-fiber Hybrid UPSR, or a 2-fiber or 4-fiber Hybrid BLSR, each with STM layer self-healing characteristics. ATM layer protection may also be provided for ATM traffic. In a UPSR, ATM layer protection is the only means used for protecting ATM traffic (see explanation in Section 2.4.2).

SONET DCS (short for pure SONET Digital Cross-Connect System):

A SONET NE with STM Broadband (STS level) and/or Wideband (VT level) Digital Cross-Connect System functionality.

ATM VPX (short for pure ATM Virtual Path Cross-Connect):

An ATM NE with ATM VP Digital Cross-Connect System functionality (an ATM DCS).

ATM VCX (short for pure ATM Virtual Channel Cross-Connect):

An ATM NE with ATM VC Digital Cross-Connect System functionality (an ATM DCS).

Hybrid DCS (short for Hybrid SONET/ATM Digital Cross-Connect System):

A Hybrid NE with STM Broadband (STS level) and/or Wideband (VT level) and ATM (VP or VC level) Digital Cross-Connect System functionality.

ATM SAM (short for ATM Service Access Multiplexer):

An ATM NE that aggregates traffic from multiple broadband service access interfaces into ATM cells placed onto a single higher speed "trunk side" interface.

Rings - Generic

SONET Ring (short for pure SONET Ring):

A ring configuration (UPSR or BLSR type) that carries only conventional SONET STM traffic. The ring consists of pure SONET ADMs with self-healing STM layer protection, but without ATM layer visibility.

SONET ATM VP Ring:

A ring configuration with a SONET physical layer that may either carry ATM traffic exclusively (**Pure ATM Ring**, see below) or that may be able to carry a combination of ATM and STM traffic (**Hybrid Ring**, see below).

Pure ATM Ring:

A ring configuration (UVPSR or BVPSR type) that carries only ATM cells at the ATM VP layer on SONET STS-1s or STS-Ncs, or on a non-SONET physical layer, for example DS3. The ring consists of pure ATM ADMs and does not have self-healing STM layer protection; ATM VP layer protection will take its place.

Hybrid Ring (short for Hybrid SONET/ATM Ring):

A SONET ring configuration (UPSR or BLSR type, with or without VP protection) that carries SONET STM traffic on some of the STS-Ns and ATM cells on other STS-Ns (STS-1s or STS-Ncs). The ring consists of Hybrid ADMs, and in addition it may also contain pure SONET ADMs, both with self-healing STM layer protection. The ring may also provide ATM layer protection for ATM traffic.

Rings - Specific

SONET UPSR (short for pure SONET Unidirectional Path-Switched Ring):

A 2-fiber SONET Unidirectional Path-Switched Ring consisting of SONET ADMs with self-healing STM layer protection (path switches).

SONET BLSR (short for pure SONET Bidirectional Line-Switched Ring):

A 2-fiber or 4-fiber SONET Bidirectional Line-Switched Ring consisting of SONET ADMs with self-healing STM layer protection (ring switches, and also span switches in the 4-fiber BLSR).

ATM UVPSR (short for pure ATM Unidirectional Virtual Path Switched Ring):

A pure ATM Ring consisting of pure ATM ADMs, using unidirectional routing, with an ATM VP layer protection mechanism that is modeled after the SONET UPSR protection mechanism for STM traffic. It does not have the STM layer self-healing characteristics found in SONET rings.

ATM BVPSR (short for pure ATM Bidirectional Virtual Path Switched Ring):

A pure ATM Ring consisting of pure ATM ADMs, using bidirectional routing, with an ATM VP layer protection mechanism that might be modeled after the SONET BLSR protection mechanism for STM traffic. It does not have the STM layer self-healing characteristics found in SONET rings.

Hybrid VP UPSR (short for Hybrid SONET/ATM Virtual Path Unidirectional Path-Switched Ring):

A Hybrid Unidirectional Path-Switched Ring consisting of Hybrid ADMs. The ring may also include pure SONET ADMs. It provides ATM layer protection at the VP level for ATM traffic. It also provides self-healing STM layer protection, but only for the STS-Ns that carry SONET STM signals (path switches). STM layer protection cannot protect ATM traffic (see explanation in Section 2.4.2).

Hybrid VP BLSR (short for Hybrid SONET/ATM Virtual Path Bidirectional Line-Switched Ring):

A Hybrid Bidirectional Line-Switched Ring consisting of Hybrid ADMs. The ring may also include pure SONET ADMs. It provides ATM layer protection at the VP level for ATM traffic. It also provides self-healing STM layer protection for at least the STS-Ns that carry SONET STM signals (ring switches, and also span switches for the 4-fiber BLSR).

Hybrid UPSR (short for Hybrid SONET/ATM Unidirectional Path-Switched Ring):

A Hybrid Unidirectional Path-Switched Ring consisting of Hybrid ADMs. The ring may also include pure SONET ADMs. There is no ATM layer protection for ATM traffic. There is self-healing STM layer protection, but only for the STS-Ns that carry

SONET STM signals (path switches). STM layer protection cannot protect ATM traffic (see explanation in Section 2.4.2).

Hybrid BLSR (short for Hybrid SONET/ATM Bidirectional Line-Switched Ring):

A Hybrid Bidirectional Line-Switched Ring consisting of Hybrid ADMs. The ring may also include pure SONET ADMs. There is no ATM layer protection. There is self-healing STM layer protection for at least the STS-Ns that carry SONET STM signals (ring switches, and also span switches for the 4-fiber BLSR).

ATM Switches

ATM BSS (short for ATM Broadband Switching System):

A large capacity ATM switch usually placed in the core network and often referred to as an ATM Hub Switch. It may act as a tandem switch or as a local switch or as a combined tandem/local switch.

ATM ES (short for ATM Edge Switch):

A small ATM switch placed at the edge of the ATM network. It acts as a local switch directly serving subscribers/users.

Table 2-1 lists the six types of SONET rings with ATM VP capabilities that have been identified.

Table 2-1. Summary of SONET ATM VP Ring Types

	Ring Type	Transport (Add/Drop)		Protection Layer for STM traffic		Protection Layer for ATM traffic	
		STM	ATM cells	STM	ATM VP	STM	ATM VP
Hybrid Ring	**Hybrid VP UPSR**	√	√	√	-	-	√
	Hybrid VP BLSR	√	√	√	-	-	√
	Hybrid UPSR	√	√	√	-	-	-
	Hybrid BLSR	√	√	√	-	√	-
Pure ATM Ring	**ATM UVPSR**	-	√	-	√	-	√
	ATM BVPSR	-	√	-	√	-	√

The last two types shown in the table are pure ATM Rings consisting of pure ATM NEs which may be used for pure ATM networks. These six types are in addition to the two types

of conventional SONET Rings, the SONET UPSR and the SONET BLSR, which are not discussed further here. The table provides the naming convention for SONET ATM VP Rings. The following guidelines are used to define the ring types based on their respective transport and protection mechanisms:

- Transport: If a ring supports the adding and dropping of both, STM and ATM VP traffic, then Hybrid is used as the first term. A ring supporting the adding and dropping of ATM VP traffic only (with CES for STM traffic, if applicable), uses ATM as the first term.
- STM Protection: In a Hybrid Ring, the type of SONET Ring, UPSR or BLSR, is used as the last term, indicating the type of STM layer self-healing ring protection. The BLSR type includes both, 2-fiber as well as 4-fiber rings. It is assumed that in Hybrid Rings STM traffic is always protected at the STM layer, unless STM traffic is carried in the form of CES. Pure ATM Rings (i.e., ATM UVPSR and ATM BVPSR) may also carry STM traffic in the form of CES and protect such traffic at the ATM VP layer.
- ATM Protection: If ATM VP layer protection is used to protect the ATM traffic, then the term VP is used after the term Hybrid or ATM as follows. A Hybrid Ring with VP protection for the ATM traffic is classified as Hybrid VP. A pure ATM ring with VP protection is classified as ATM UVPSR or ATM BVPSR, depending on the type of protection employed. The ATM UVPSR protection mechanism is modeled after the SONET UPSR dedicated protection mechanism for STM traffic; an example is shown in Figure 3-9. The ATM BVPSR uses bidirectional routing and its protection mechanism might be modeled after the SONET BLSR shared protection mechanism for STM traffic but has not been defined yet. It is assumed that in Hybrid VP Rings ATM traffic is always protected at the ATM VP layer. However, a Hybrid BLSR may protect ATM traffic at the STM layer.

Table 2-2 provides another view on how different combinations of transport multiplexing and transport protection can be implemented. The table illustrates how the different types of rings previously defined can potentially be deployed to carry different traffic types with different protection mechanisms. The rows indicate transport multiplexing options including only STM multiplexing (i.e., all traffic carried in STM format with no ATM processing on the ring), ATM multiplexing (i.e., all traffic carried in ATM format and processed via ATM multiplexing) and Hybrid multiplexing (i.e., some traffic carried in STM format and some traffic carried in ATM format).

The columns indicate the protection layer used. The options are SONET layer protection for all traffic, ATM layer protection for all traffic, and both SONET and ATM layer protection. When only STM traffic is carried, the existing SONET layer protection mechanisms can be used. This is the case for existing SONET UPSR and BLSR rings. As noted above, these rings can carry ATM traffic but the ATM characteristics are transparent to the rings that only process and protect traffic at the SONET layer.

When all traffic is carried in ATM format and only SONET layer protection is provided, only the Hybrid BLSR can be used where the ATM traffic is multiplexed with ATM

Table 2-2. Summary of Ring Transport Multiplexing and Protection Switching Alternatives

	SONET Layer Protection Only	ATM Layer Protection Only	SONET and ATM Layer Protection
STM Multiplexing Only (i.e., STM traffic only on ring)	**- SONET UPSR** **- SONET BLSR** (Conventional SONET)	- Not applicable (assuming only STM multiplexing and STM traffic)	- Not applicable (assuming only STM multiplexing and STM traffic)
ATM Multiplexing Only (i.e., ATM traffic only on ring)	**- Hybrid BLSR** (ATM traffic protected by SONET layer)	**- ATM UVPSR** **- ATM BVPSR** (ATM traffic protected by ATM layer)	**- Hybrid VP UPSR** **- Hybrid VP BLSR** (SONET layer protection disabled)
Hybrid (STM and ATM) Multiplexing (i.e., both STM and ATM traffic on ring)	**- Hybrid BLSR** (All traffic protected by SONET layer)	**- ATM UVPSR** **- ATM BVPSR** (STM traffic via CES, protected by ATM layer)	**- Hybrid VP UPSR** **- Hybrid VP BLSR**

mechanisms but protection is provided via the existing SONET BLSR STM protection protocol. Note that this mechanism has limitations in how effective it is for protecting ATM traffic. Sole reliance on the existing SONET BLSR STM protection mechanism can potentially result (under certain failure conditions) in unnecessary squelching of ATM traffic (unless the current squelching protocol is modified) to account for ATM Virtual Path connections on the ring. The Hybrid UPSR does not protect ATM traffic via the existing SONET UPSR STM protection protocol (see explanation in Section 2.4.2).

Another alternative for the case of all ATM traffic is to use ATM UVPSR or ATM BVPSR rings that can only provide ATM layer protection mechanisms (i.e., these rings are not designed to provide SONET layer protection mechanisms). Another possibility for the case of all ATM traffic is to utilize the Hybrid Rings that can provide ATM VP protection (i.e., Hybrid VP UPSR, Hybrid VP BLSR) but to disable the SONET layer protection since all traffic is carried in ATM format. Since 100% of the traffic is carried in ATM format, all of this traffic would be protected using ATM mechanisms. Note that if there was a change of traffic on the ring (e.g., some traffic was carried in STM format), the SONET protection mechanisms could be enabled for the Hybrid Rings.

For the case of mixed STM and ATM traffic, it is possible to utilize rings that only implement SONET layer protection (i.e., Hybrid BLSR). As noted previously, one consideration is that using the SONET layer protection for ATM traffic may impose some limitations. It is also possible to utilize rings that only implement ATM layer protection

(i.e., ATM UVPSR and ATM BVPSR) if the STM traffic is carried via CES. In rings that implement both, SONET as well as ATM layer protection (i.e., Hybrid VP UPSR and the Hybrid VP BLSR), the SONET layer protection is used for SONET traffic and the ATM layer protection mechanism is used for ATM traffic.

The following sections describe the NEs defined above in more detail and show how they may be deployed in networks. The NEs are grouped as follows:

- Conventional SONET Transport NEs
  1. SONET Add/Drop Multiplexer (ADM) - Linear and Ring
  2. SONET Digital Cross-Connect System (DCS) - Wideband and Broadband
- ATM Transport NEs
  1. ATM Service Access Multiplexer (SAM)
  2. ATM Add/Drop Multiplexer (ADM) - Linear and Ring
  3. ATM Cross-Connect
- ATM Switches
  1. ATM Edge Switch (ES)
  2. ATM Hub Switch (BSS)
- Hybrid Transport NEs
  1. Hybrid ADM
  2. Hybrid DCS.

2.2.2 Conventional SONET Transport NEs

2.2.2.1 SONET ADM

A SONET ADM adds and drops a variety of digital signals from a SONET OC–N signal that passes through on the high-speed side. The added and dropped signals at the low-speed ports of a SONET ADM may be SONET STM or DSn (e.g., DS1 and DS3) signals. The SONET STM signals are OC-M signals that are multiplexed into the higher speed OC–N signal (M≤N). A SONET ADM may be used in linear chain applications or in ring configurations. A SONET Ring ADM may be configured for use in a Unidirectional Path-Switched Ring (UPSR) or a Bidirectional Line-Switched Ring (BLSR), each with STM layer self-healing characteristics. The latter provide high survivability with very fast service restoration in the case of failures. These ring types and their characteristics are briefly described in the following two sections. Requirements for basic SONET Add/Drop Multiplexer functionality can be found in TR–NWT–000496.

A ring composed only of SONET ADMs is limited to transporting ATM cells added/dropped as a whole SONET payload (i.e., STS–Nc SPE) or DSn payload. It does not have the capability of dropping individual ATM cells that may be carried within the SONET or DSn payloads.

2.2.2.2 Unidirectional Path-Switched Ring Overview

A Unidirectional Path-Switched Ring[1] (UPSR) is a 2-fiber ring where the two transmission directions of a working path (e.g., A-to-B and B-to-A) travel around the ring in **one direction**[2] on one fiber, and the two transmission directions of a protection path in the other direction on the other fiber. Figure 2-6 shows the UPSR structure for an OC-N ring. Traffic from A to B entering the ring is dual-fed at the source node (A) in both directions around the ring, on the working fiber in one direction, and on the protection fiber in the other direction. At the destination node (B), a path selector selects the better of the two received signals to exit the ring. Traffic from B to A is handled in the same manner. Figure 2-6 shows only one path, a path between nodes A and B (both directions). This path could be an STS path, or a VT path. A ring can carry many such paths between many node pairs on the ring.

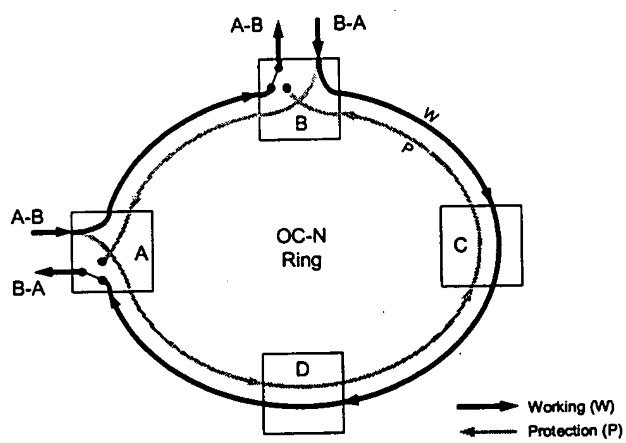


Figure 2-6. Unidirectional Path-Switched Ring (UPSR)

The total bandwidth for all paths carried on the UPSR is limited to OC-N and is shared by all nodes on the ring. Bandwidth in non-overlapping sections of the ring cannot be reused. The UPSR provides protection against single line (or link) failures or single node failures.

1. The term "unidirectional" in the UPSR refers to the traffic direction around the ring and should not be confused with the fact that the UPSR is designed for bidirectional symmetric transmission.
2. Since both transmission directions of working paths travel around the ring in **one direction** (i.e., in the clockwise direction in the example in Figure 2-6), the ring is called a **"unidirectional"** ring.

A cable cut between A and B in Figure 2-6, for example, would cause the selection of the A-to-B path from the protection fiber, and would leave the B-to-A path untouched on the working fiber. GR-1400-CORE provides generic criteria for SONET UPSR equipment.

2.2.2.3 Bidirectional Line-Switched Ring Overview

A Bidirectional Line-Switched Ring (BLSR) can be a 2-fiber or a 4-fiber ring, where the two transmission directions of a working path travel on the same route in opposite directions. Protection switching is performed at the line level, whereas it is done at the path level in the UPSR. Protection mechanisms are slightly different between the two types of BLSRs, as explained in the following. GR-1230-CORE provides generic criteria for SONET 2-fiber and 4-fiber BLSR equipment.

Figure 2-7 shows the 2-fiber BLSR structure for an OC-N ring. Protection is provided by reserving half the bandwidth (half the time slots) on each fiber for protection. The working half of each fiber (W1 and W2) is protected by the protection half on the other fiber (P1 and P2, respectively), traveling around the ring in opposite direction. This limits the span capacity to OC-N/2 (half the bandwidth of OC-N); however, bandwidth in non-overlapping sections of the ring can be reused. A cable cut between A and B, as indicated in Figure 2-7, causes the ADMs in the two adjacent nodes to perform a ring switch at the line level (a loop back), connecting all working channels facing the cable cut to the protection channels in the opposite direction. This mechanism provides protection against single line failures or single node failures.

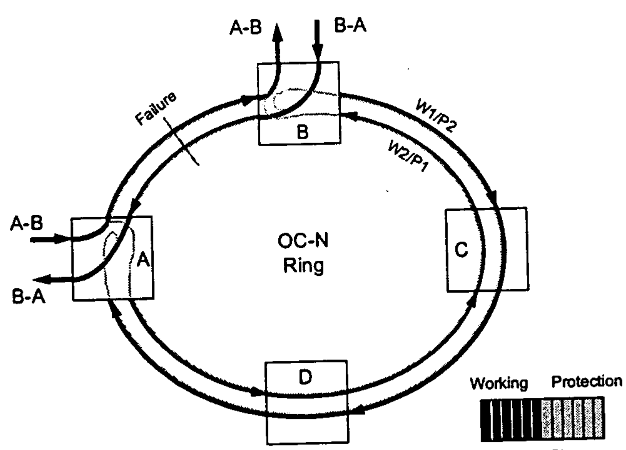


Figure 2-7. Two-Fiber Bidirectional Line Switched Ring (BLSR)

Figure 2-8 shows the 4-fiber BLSR structure for an OC-N ring. Protection is provided by two separate protection fibers in addition to the two working fibers. This allows a span capacity of OC-N, and further, bandwidth in non-overlapping sections of the ring can be

reused. A cable cut between A and B, as indicated in Figure 2-8, causes the ADMs in the two adjacent nodes (A and B) to perform a ring switch at the line level (a loop back), connecting the working fibers facing the cable cut to the protection fibers in the opposite direction. This mechanism provides protection against single line failures or single node failures.

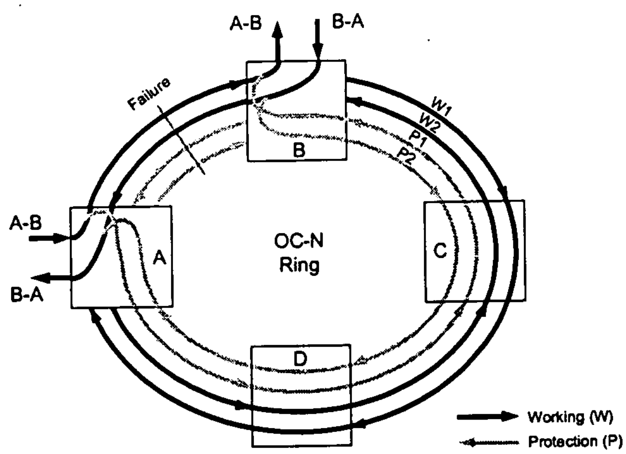


Figure 2-8. Four-Fiber Bidirectional Line Switched Ring (BLSR) - Ring Switch

A second protection mechanism is available in the 4-fiber BLSR. A failure that affects only the working fibers between A and B, as shown in Figure 2-9, can be protected by a span switch between adjacent nodes (A and B), very similar to protection switching in a point-to-point architecture.

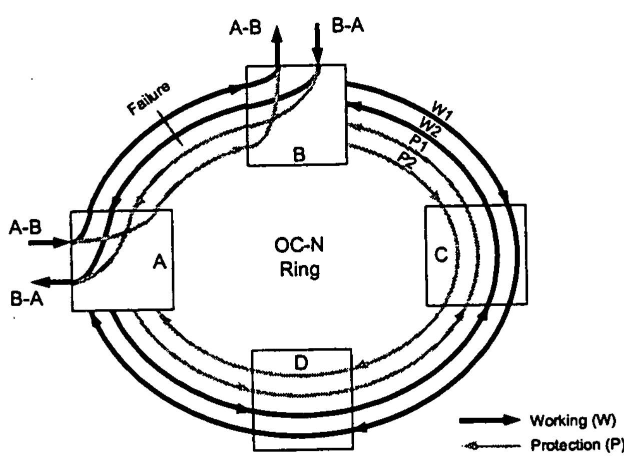


Figure 2-9. Four-Fiber Bidirectional Line Switched Ring (BLSR) - Span Switch

2.2.2.4 SONET DCS

A SONET DCS can be categorized as either a SONET Wideband DCS (W-DCS) or a SONET Broadband DCS (B-DCS). A SONET W-DCS cross-connects at the VT1.5 level (i.e., has a VT1.5 cross-connect matrix) and provides SONET signal termination and multiplexing. The SONET interfaces may be STS–1, STS–3, or OC–N. In addition, the SONET W-DCS may provide DS1 and DS3 interfaces. A SONET B-DCS cross-connects at the STS–1 or higher level (i.e., has an STS–1 or higher cross-connect matrix) and provides SONET signal termination and multiplexing. The SONET interfaces may be STS–1, STS–3, or OC–N. In addition, the SONET B-DCS may provide DS3 interfaces.

The SONET DCS performs many functions such as grooming, add/drop, broadcast, facility rolling, performance monitoring, test access, and remote configuration. Each of these functions are described in GR–2891–CORE.

Grooming is a function that allows efficient use of both incoming and outgoing facilities by the cross-connection of tributaries. Grooming includes consolidation and segregation.

Consolidation improves the fill factor of a given facility by combining tributaries from partially filled incoming facilities into a smaller number of more highly utilized outgoing facilities. This maximizes the use of existing high-speed transport facilities, and reduces the equipment needed in the office. **Segregation** simplifies maintenance and route restoration procedures by sorting out mixed tributaries on incoming facilities by service type, destination, or protection category, resulting in uniform content on outgoing facilities.

An **add/drop** function is provided by DCSs with a multiplexing function, allowing access to incoming and outgoing tributaries embedded within a terminating high-speed facility. Such tributaries may then be added and dropped. This is the same function provided by the ADM, but it allows higher flexibility by providing Time Slot Interchange (TSI) capability. An ADM usually only provides the Time Slot Assignment (TSA) capability[3].

In ring applications, a conventional DCS is normally deployed between rings, without being a part of the ring. An enhanced type of DCS is a SONET ring DCS. Even though the ring DCS can be used to provide the same basic functions as an ADM does, the major impetus to the deployment of SONET ring DCSs is the capability of such DCSs to provide ring transport functions for more than one ring, thus providing direct ring interconnection. GR–1375–CORE covers SONET DCSs with ring functionality.

Basic ATM transport capability in a DCS can be provided by simple intact mapping of STS–1, STS–3c, or STS–12c through the STM fabric of a SONET DCS.

3. TSI permits mapping of a time slot on an east side high-speed port to any other time slot on a west side high-speed port, or to any low-speed drop port. TSA permits mapping of a time slot on the east side high-speed port only to the same numbered time slot on the west side high-speed port, or to any low-speed drop port.

2.2.3 ATM Transport NEs

2.2.3.1 ATM SAM

The SAM is an ATM service access node typically deployed at the edge of a public ATM network. The basic function of the SAM is to aggregate traffic from multiple broadband service access interfaces and to deliver this service traffic via a single high-speed interface to a BSS or an Edge Switch (ES) for service feature processing and switching as depicted in an example in Figure 2-10.

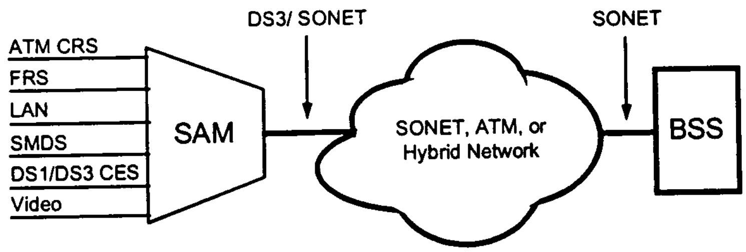


Figure 2-10. Example of SAM Deployment

By aggregating traffic, the SAM provides a highly filled interface either directly to an ATM switch (a BSS or an ES) or indirectly through a network (a SONET, ATM, or Hybrid network). Services supported may include:

1. SMDS
2. PVC FRS
3. PVC CRS
4. Native Mode Local Area Network (LAN) Interconnection Service
5. DS1/DS3 CES
6. Video
7. XDSL based Services.

SAMs optimized for supporting XDSL (e.g., ADSL) interfaces to subscribers are called Digital Subscriber Line Access Multiplexers (DSLAMs).

The SAM function can be realized either in a stand-alone NE or it can be integrated into another NE such as a Hybrid ADM or Hybrid DCS. If the SAM function is implemented in a Hybrid NE, then the SAM Interface (SAMI) at the SAM is one of the internal STS paths, as shown in Figure 2-11. The SAM would interface to the SONET STM function at the

Synchronous Payload Envelope (SPE) layer. The requirements and more detailed description of the SAM functions can be found in GR-2842-CORE.

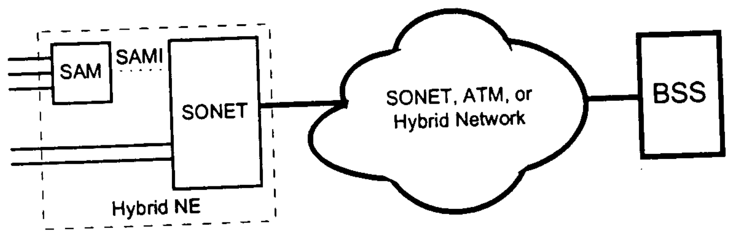


Figure 2-11. Example of SAM Function Implemented in Hybrid NE

2.2.3.2 ATM ADM

Pure ATM ADMs are similar to SONET ADMs, except that they add and drop ATM VP signals at their low-speed ports. These signals are part of the transport capacity that passes between the high-speed ports. The high-speed ports may use SONET STS-N or STS-Nc or other physical layer interfaces for the transport of ATM cells. At the high-speed interfaces, the SONET or other physical layer is always terminated, even if the ATM cells pass through the ADM without adding and dropping. This termination is another difference when compared to SONET ADMs.

An ATM ADM may be used in linear chain applications or in ring configurations. The pure ATM Ring ADM does not have the STM layer self-healing characteristics found in SONET rings. However, ATM VP layer protection will provide another type of self-healing. Depending on the capabilities built into a pure ATM Ring ADM, it may support one or more of the two types of pure ATM Rings: ATM UVPSR and ATM BVPSR (see Table 2-1).

Different types of ATM functionality could be envisioned for pure ATM ADMs. Besides the basic ADM function, additional capabilities could also include selected functions of a BSS (GR-1110-CORE), SAM (GR-2842-CORE), or VPX (GR-2891-CORE). An interesting additional function would be to provide STM interfaces with STM/ATM conversion through AAL1 type circuit emulation (as shown in Figure 2-5, method 3 for ATM Transport). This would enable the ADM to transparently pass or add and drop STM signals (i.e., DSn and STS-N) that are converted into an ATM cell stream.

2.2.3.3 ATM Cross-Connect

ATM cross-connects allow for cell traffic management and intermediate cell grooming between BSSs, and between BSSs and SAMs or ESs. In contrast to a BSS, an ATM cross-connect provides semipermanent connections according to an alterable memory map; it

will not require such functionality as real-time switching with call and connection signaling. In other words, an ATM cross-connect will only play a role in establishing PVCs, while a BSS can establish both PVCs and SVCs. The lesser complexity of the ATM cross-connect should result in a more economical NE at locations where real-time switching is not required. An ATM cross-connect can, however, be part of a network that provides SVC services that are controlled by the BSS. It can support SVC passively by passing signalling messages (via a VC service providing a point-to-point signaling channel) without processing them. This is also referred to as "Signaling Tunneling."

Two types of ATM cross-connects have been defined, one that operates at the ATM Virtual Path level and one that operates at the ATM Virtual Channel level. They are referred to as an ATM Virtual Path Cross-Connect (ATM VPX) operating at the ATM VP level and an ATM Virtual Channel Cross-Connect (ATM VCX) operating at the ATM VC level.

The ATM VPX is more suitable in the core network, at major hub nodes, during the more mature development stage for heavy ATM traffic, or for start-up deployments when there are no existing SONET DCSs. It cross-connects VPs and processes VPIs only. It is transparent to VCs and VCIs. As a result of its reduced processing complexity, the ATM VPX may be a more economical NE in the core network than the ATM VCX. Also, in a network that supports SVC services in addition to PVC services, using an ATM VPX for PVCs may be more economical than using BSSs for both SVCs and PVCs.

The ATM VCX is most suitable for lower density ATM traffic close to the network edges during early development stages with sparse channel densities. It cross-connects VCs and processes VPIs and VCIs together; and it provides associated management functions. It could also provide statistical multiplexing of VCs within a VP.

More detailed information and requirements for the ATM VPX and ATM VCX functions can be found in GR–2891–CORE.

Figure 2-12 illustrates an advanced model of the ATM VPX (Figure 2-13 provides a more detailed view of the STM/ATM conversion portions that include M13 multiplexing functions and AAL1 circuitry). This advanced ATM VPX goes a step beyond the pure ATM VPX by adding SONET STM interfaces with STM/ATM conversion through circuit emulation. This type of ATM cross-connect would be able to cross-connect ATM as well as STM type traffic and thus would be suitable for Hybrid networks. STM capability in the VPX and VCX could be achieved by converting incoming STM signals into ATM cells (through AAL1 type circuit emulation) that can be cross-connected by the ATM VP or VC matrix, and then reassembling the ATM cells into the original STM signals at the output.

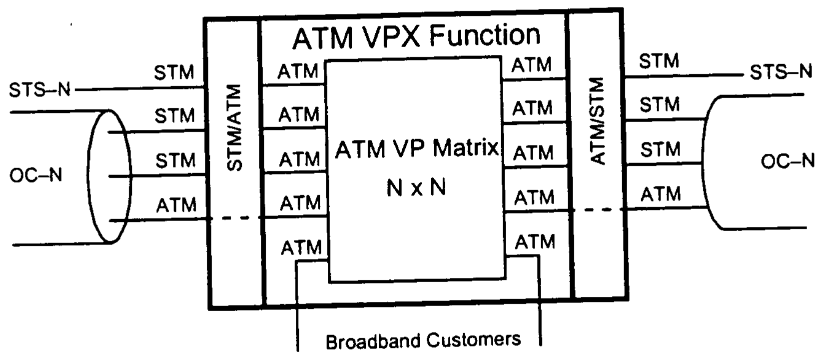


Figure 2-12. ATM VPX with SONET STM Capability

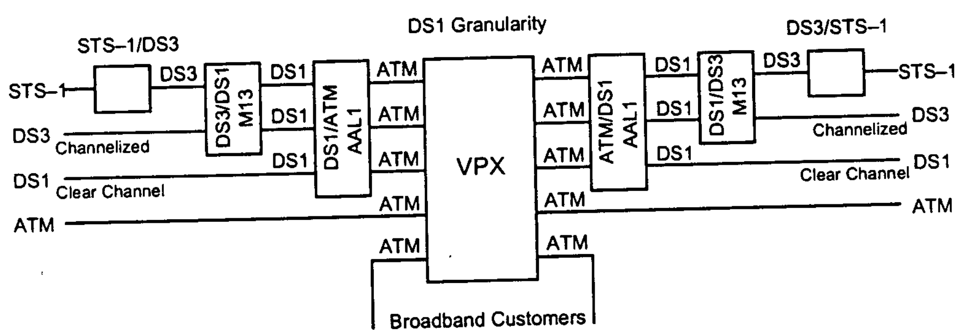


Figure 2-13. ATM VPX with W-DCS 3/1 Capability - More Detailed View

2.2.4 ATM Switching Systems

2.2.4.1 ATM Edge Switch (ES)

An ATM Edge Switch (ES) is an ATM Switch with less capacity than a Broadband Switching System (BSS). The BSS is described in Section 2.2.4.2.

2.2.4.2 ATM Hub Switch (BSS)

Requirements pertaining to a Broadband Switching System (BSS) can be found in GR–1110–CORE. In many architecture alternatives, ESs are not deployed in the access subnetwork and therefore all ATM traffic must be transported to a few BSSs located in the interoffice subnetwork. Thus a BSS is often referred to as an ATM Hub Switch. In

conventional SONET networks the BSS, ES, and SAM are normally the only NEs in the network that perform ATM processing functions. Services supported by a BSS include:

- Permanent Virtual Connection (PVC) Cell Relay Services (CRS)
- Switched Virtual Connection (SVC) CRS
- Switched Multi-Megabit Data Services (SMDS)
- PVC Frame Relay Service (FRS)
- DS1/DS3 Circuit Emulation Service (CES)
- LAN Interconnection.

2.2.5 Hybrid Transport NEs

It is expected that the evolution of early ATM services will in many cases utilize existing SONET networks in a Hybrid SONET STM and ATM network approach. For such applications, it may be beneficial to add ATM functionality to SONET NEs, permitting the gradual addition and growth of ATM services over existing SONET networks. This leads to the Hybrid ADM and the Hybrid DCS described in the following sections.

2.2.5.1 Hybrid ADM

A Hybrid ADM is a SONET ADM to which ATM cell processing capabilities have been added. These capabilities include adding and dropping ATM traffic as well as policing. To provide such ATM capability, an upgrade of existing SONET ADMs is necessary. Hybrid ADMs can work side by side with SONET ADMs. In a network, ADMs that need to drop ATM traffic can be upgraded to Hybrid ADMs to provide ATM cell processing, whereas ADMs that need to only drop STM traffic do not need to be upgraded. A Hybrid ADM may be used in linear chain applications or in ring configurations. A Hybrid Ring ADM may be capable for use in a UPSR or a BLSR with STM layer self-healing characteristics. ATM VP layer protection may also be provided and can be viewed as another type of self-healing. Depending on the capabilities built into a Hybrid Ring ADM, it may support one or more of the four types of Hybrid Rings: Hybrid UPSR, Hybrid BLSR, Hybrid VP UPSR, and Hybrid VP BLSR (see Table 2-1).

Different types of ATM functionality could be envisioned for Hybrid ADMs. Besides the basic ADM function, additional capabilities could also include selected functions of a BSS (GR-1110-CORE), SAM (GR-2842-CORE), or VPX (GR-2891-CORE).

2.2.5.2 Hybrid DCS

A Hybrid DCS is a SONET DCS to which ATM cell processing capabilities have been added. These capabilities include cross-connecting, adding, and dropping ATM traffic as well as policing. To provide such ATM capability, an upgrade of existing SONET DCSs is necessary. ATM functionality is made possible in a Hybrid DCS by adding an ATM cross-connect matrix. The ATM cross-connect matrix along with an STM cross-connect matrix are the two major components of a Hybrid DCS. Pure ATM cross-connects have been discussed earlier in Section 2.2.3.3.

ATM functionality in Hybrid DCSs covers a wide range of potential implementations. GR-2891-CORE divides the range into three levels of ATM functionality and provides requirements for each level. Table 2-3 provides an organized reference distinguishing the three levels of ATM functionality. A Level 1 DCS is a SONET DCS (discussed in Section 2.2.2.4), and, while not a true Hybrid DCS, provides cross-connection of ATM traffic through simple intact mapping of STS-1, STS-3c, or STS-12c through the STM fabric of a SONET DCS. The Hybrid DCS is defined as having Level 2 ATM functionality or Level 3 ATM functionality.

Table 2-3. Properties of DCS ATM Functionality Levels

Level of ATM Functionality	STM Matrix	ATM Matrix	Ring Functionality
Level 1	√		
Level 2	√	√	
Level 3	√	√	√

Figure 2-14 and Figure 2-15 show a Hybrid DCS with level 2 ATM functionality. A Level 2 Hybrid DCS can cross-connect STM signals (such as VT1.5 or STS-1) as well as ATM cells by utilizing two different fabrics (STM and ATM). A Level 3 Hybrid DCS has the same functions as a Level 2 Hybrid DCS; however, it is also equipped with self-healing ring protection functionality.

In Figure 2-14, OC-N interfaces contain either all STM tributaries and are connected to the STM cross-connect matrix, or they contain all ATM tributaries and are connected to the ATM VP cross-connect matrix. This configuration requires upstream segregation of STM and ATM signals. In Figure 2-15, OC-N interfaces may contain a mixture of STM and ATM tributaries; they are internally demultiplexed (or multiplexed), and the tributaries are forwarded to the appropriate cross-connect matrix.

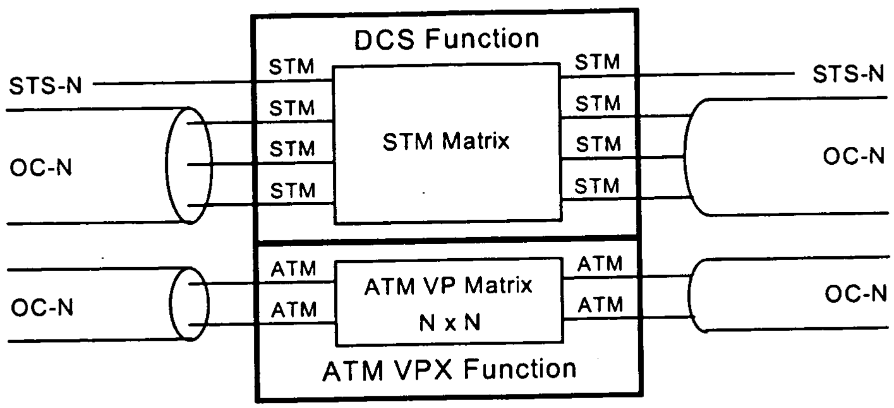


Figure 2-14. Hybrid DCS - Segregated Interfaces

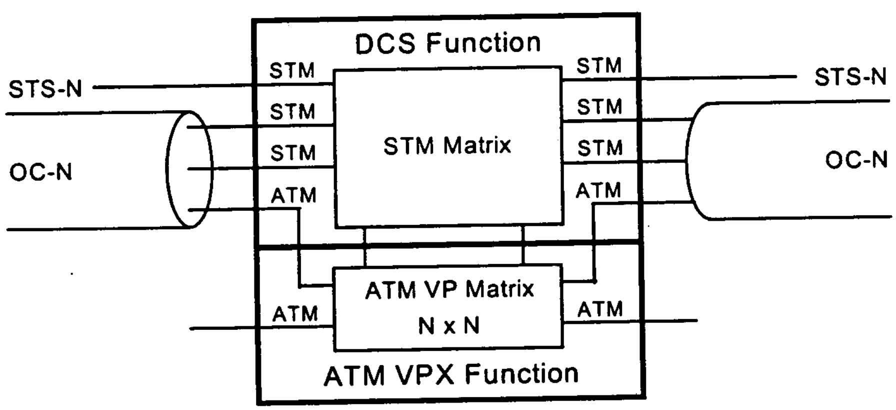


Figure 2-15. Hybrid DCS - Mixed Interfaces

2.2.6 Subnetwork Architectures

A network may be divided into the following subnetworks and functions:

1. Access Transport
2. Interoffice Transport
3. Grooming
4. Switching.

The evolution of a SONET transport network into an ATM transport network capable of efficiently carrying ATM traffic involves upgrades to the various subnetworks. For example, a near to mid term evolution from a conventional SONET access ring subnetwork

could involve (1) selectively upgrading the existing SONET ADMs into Hybrid ADMs, or (2) adding ESs or SAMs to provide customers with efficient ATM access. For those SONET ADMs that do not drop or add ATM traffic, an ATM upgrade does not provide any benefit to the overall efficiency of the network, and thus would not be needed.

The following sub-sections describe different architecture alternatives for each of the subnetworks. The architecture alternatives will depend on many variables including ATM demand.

2.2.6.1 Access Transport

In the conventional SONET ring transport network, a SONET ring NE at the access subnetwork provides transparent transport of ATM traffic onto the Interoffice (IOF) network. These NEs do not provide any means for switching or cross-connection of ATM traffic. The ATM traffic is switched in the IOF network (via a BSS) and sent back to the access network for delivery to the customers. As the amount of ATM traffic increases in the network, this process of providing all switching in the IOF network may become less desirable. The process of delivering all ATM traffic to a few hub ATM switches in the IOF network may cause bottlenecks and excessive backhaul costs as the amount of ATM traffic increases.

Deploying only conventional SONET NEs in the access network leads to inefficient use of bandwidth when transporting ATM traffic. For example, assume customers A and B wish to transport 10 Mb/s and 20 Mb/s of ATM traffic through the network, respectively. If only conventional SONET NEs are deployed in the access network, each customer would require a DS3 to connect to the BSS, as shown in Figure 2-16. In this example, approximately 30 Mb/s and 20 Mb/s of bandwidth is being wasted on DS3 (A) and DS3 (B), respectively. In addition, multiple interfaces to the BSS would be needed, one for each DS3.

Some of the limitations mentioned above may be overcome by deploying ATM NEs, such as SAMs and ESs, in the access network. A diagram depicting this access subnetwork architecture alternative is in Figure 2-17. The presence of the ES allows local switching (i.e. switching between customers connected to the same access ring) to be performed within the access network. Local switching minimizes the amount of ATM traffic required to be transported to the hub BSSs in the IOF network. SAMs will provide better fill of STM signals (i.e., DSn and SONET signals) with ATM traffic. For example, with the deployment of the SAM, customers A and B from the previous example could now use the same DS3 to transport their combined ATM traffic (see Figure 2-18).

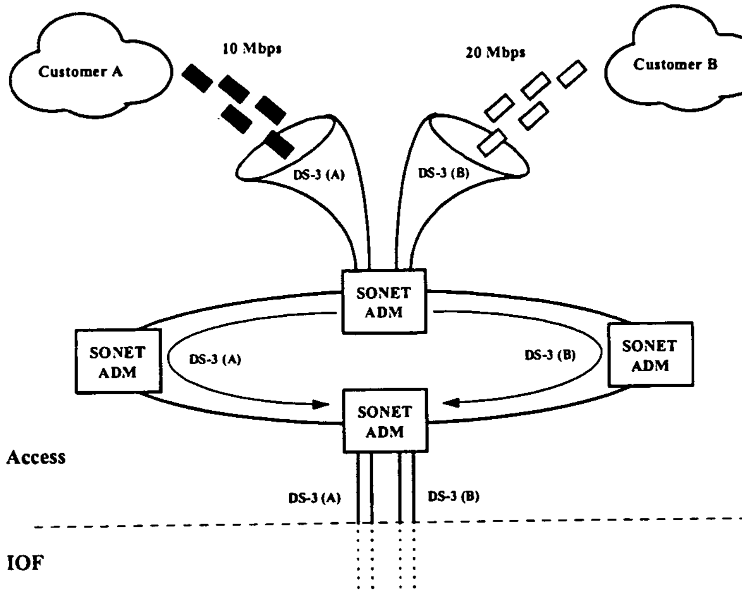


Figure 2-16. Customer ATM Access in Conventional SONET Network: Hub Demand

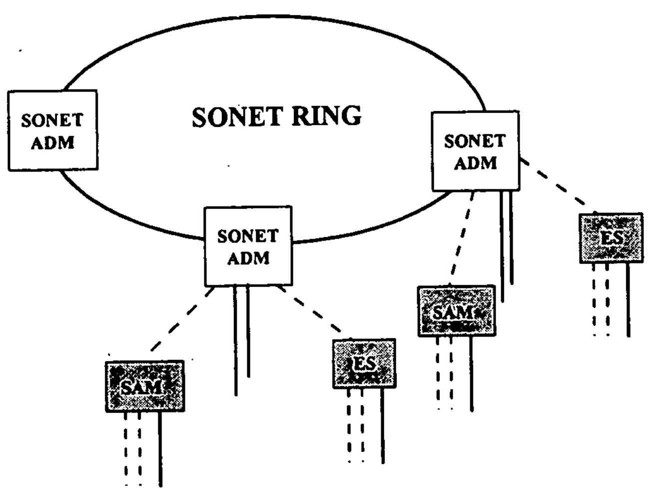


Figure 2-17. ATM NE Deployment in Conventional SONET Network

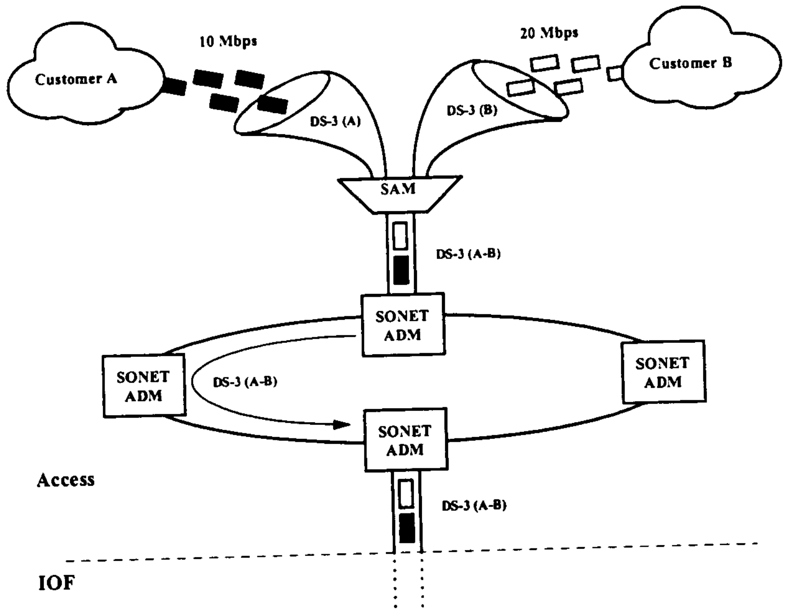


Figure 2-18. Customer ATM Access in Conventional SONET Network with SAM: Hub Demand

This architecture also has some limitations. Only ATM traffic entering and exiting the SONET ring at the same ring nodes can be transported efficiently. Traffic either entering or exiting the SONET ring at different nodes will need to be transported on separate STM signals (see Figure 2-19). With the addition of SAMs and ESs in the access network, it becomes more likely that ATM streams will be entering and exiting the rings from different nodes.

Figure 2-19 shows three 10 Mb/s ATM signals, each transported on a DS3. Since each of the three signals either enters or exits the SONET ring at different ring nodes, the process of combining the 10 Mb/s ATM signals onto a single DS3 via a SAM is not possible. Therefore the three signals must be transported through the ring in three separate STS–1 payloads. The example depicted in Figure 2-19 would require the entire capacity of an OC-3 SONET UPSR, or the equivalent capacity of two STS–1s on a BLSR. This leads to inefficient utilization of the existing bandwidth.

To provide efficient fill of the available bandwidth on the existing ring, a Hybrid Ring ADM can be used. Deploying a Hybrid Ring allows the three DS3 signals to be transported within a single STS–1 payload through the ring (see Figure 2-20).

A Hybrid Ring allows ATM streams that are added and dropped at different ring nodes to be carried on the same SONET path within the ring. When there is low ATM demand, a Hybrid Ring along with a few SAMs may provide enough bandwidth efficiency to have all

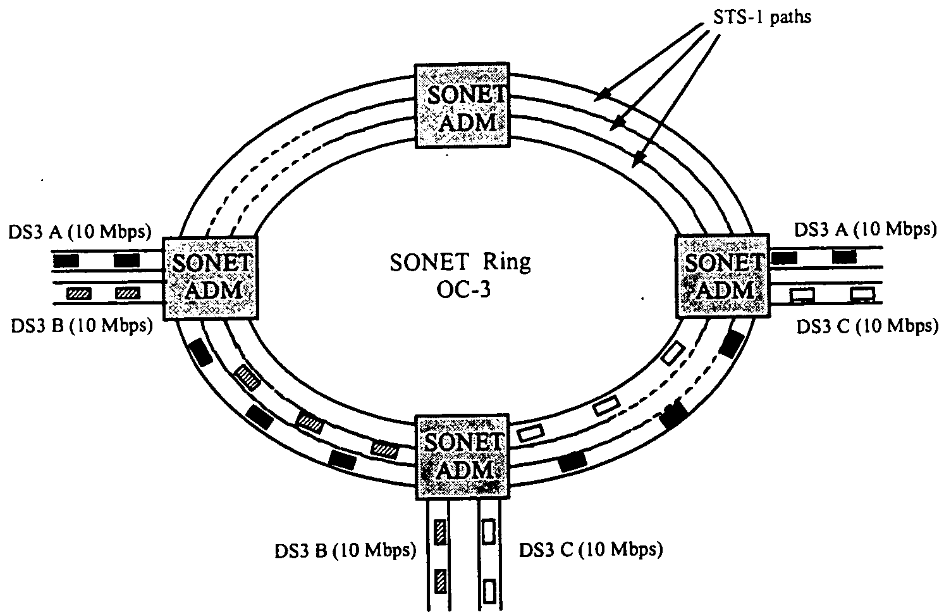


Figure 2-19. Customer ATM Access in Conventional SONET Network: Different Destinations

the ATM traffic switched at the hub BSS, thus Edge Switches would not need to be deployed in the access network. As ATM demand increases the need to deploy Edge Switches in the access network may arise to prevent congestion in the IOF network and reduce the amount of ATM traffic being backhauled through the IOF network (see Figure 2-21).

An access network architecture alternative geared for high ATM demand could be one in which Hybrid DCSs or VPX/VCX NEs are deployed as ring nodes used to interconnect Hybrid Rings (see Figure 2-22). A Hybrid DCS or VPX/VCX NE would provide grooming of ATM streams originating from many different Hybrid Rings (see Section 2.2.6.2). By deploying these NEs as ring-interconnect nodes the access network would require fewer NEs, since one Hybrid DCS or VPX/VCX could replace many Hybrid Ring Nodes. Further, some of the rings could be ATM rings with all ATM ADMs, if there is a large demand for ATM traffic.

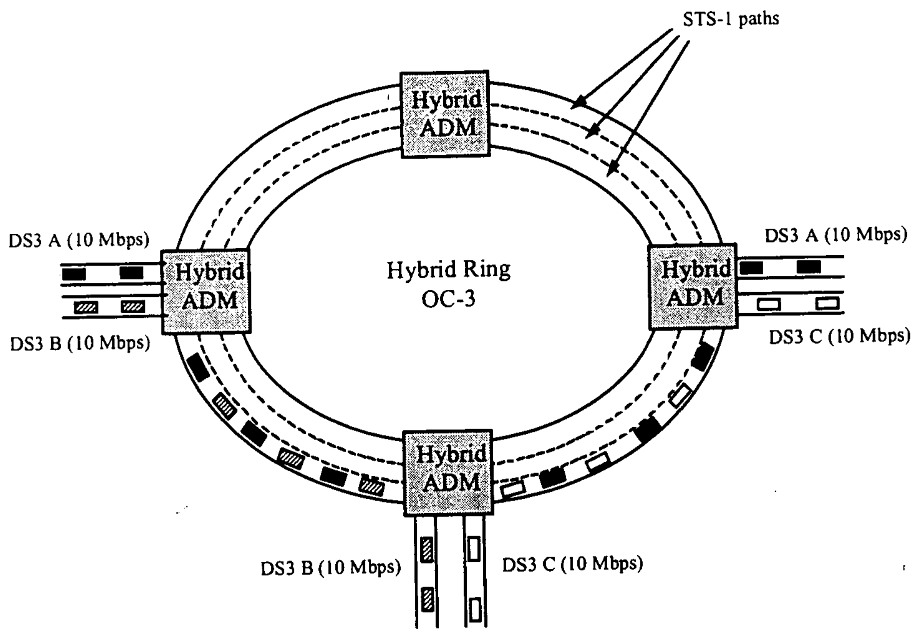


Figure 2-20. Customer ATM Access in Hybrid Network: Different Destinations

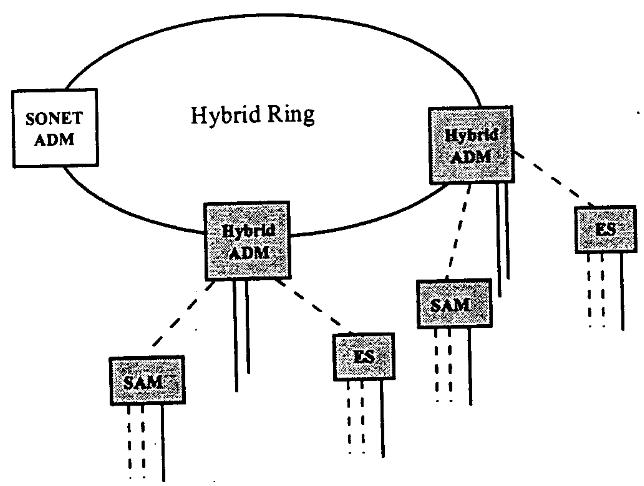


Figure 2-21. Hybrid Network with SAMs and Edge Switches Near Customer Premise

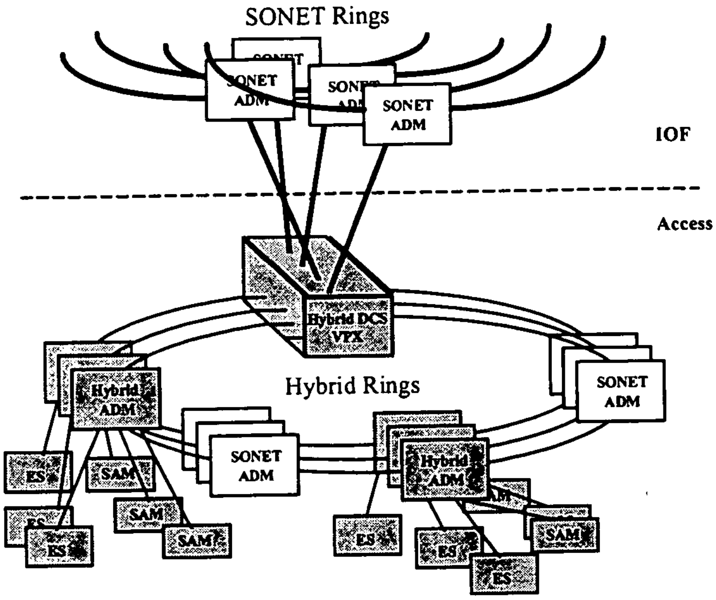


Figure 2-22. Deployment of Hybrid Cross-Connects with Ring Functionality

2.2.6.2 Interoffice Transport

The Interoffice (IOF) network transports ATM traffic originating from many access rings to a few hub ATM Switches. Initially there may not be any large advantages in deploying Hybrid equipment in the IOF network. Any ATM traffic being delivered to the IOF network will be packaged efficiently due to the deployment of Hybrid NEs in the access network. As ATM demand increases, the number of Hybrid Rings in the access network will increase. Deploying Hybrid DCSs and VPXs in the IOF network will enable ATM traffic originating from different Hybrid Rings in the access network to be groomed and therefore transported more efficiently through the IOF network.

Deploying Hybrid DCSs and VPXs in the IOF network as the ATM traffic increases will allow the access network to efficiently package SONET payloads with ATM streams destined for different BSSs. These SONET payloads can be terminated at a Hybrid DCS or VPX that could repackage the SONET payloads with ATM streams destined for the same BSS. The new SONET payloads can be more easily filled since the Hybrid DCS or VPX in the IOF network will handle ATM traffic from many different access networks.

As the number of BSSs in the IOF network increases, the need to drop different ATM streams at different ring nodes will also increase. Deploying either Hybrid ADMs or ATM ADMs in the IOF network will enable a single STS path on the IOF ring to add and drop ATM streams at different ring nodes, thus allowing more efficient packaging of the STS paths on the IOF rings. Figure 2-20 illustrates this capability for an access ring, but this concept can also apply to an IOF ring.

2.2.6.3 Grooming

Grooming can be performed in either the ATM layer or the SONET layer. Grooming at the SONET layer requires either Wideband DCSs (W-DCSs) or Broadband DCSs (B-DCSs). SONET layer grooming loads higher rate SONET signals (e.g. OC–3 or OC-12) with common lower rate SONET signals (e.g. STS–1, or STS–3). Common signals refer to all SONET signals carrying ATM traffic or all SONET signals carrying STM traffic. SONET signals carrying ATM traffic are sent to the hub BSS while SONET signals carrying STM traffic are transported to their destination. Initially, it will suffice to perform grooming only at the SONET level since the access network will have filled the SONET payloads with ATM traffic efficiently.

As discussed in Section 2.2.6.2, as the number of BSSs increase in the network, it becomes more difficult to efficiently package SONET payloads in the access network with ATM traffic if grooming is performed only at the SONET level. Performing grooming at the ATM level in the IOF network allows the access network to package ATM streams destined for different BSSs in the same SONET payload. A Hybrid DCS or VPX located in the IOF can then terminate many SONET payloads from different access rings and repackage them in order to fill SONET payloads with ATM streams destined for the same BSS.

2.2.6.4 Switching

Switching of ATM traffic can be performed by ATM ESs located in the access network and ATM Hub BSSs located in the IOF network. As discussed in Section 2.2.6.1, the deployment of ESs will decrease the amount of ATM traffic that must be transported to the Hub BSSs, thus avoiding excessive backhauling of ATM traffic and reducing the risk of congestion in the IOF network.

2.3 Efficiency of ATM Transport in Hybrid Rings

To provide efficiency of ATM transport on a Hybrid Ring, a path is provisioned to only carry ATM traffic, utilizing an STS-1, STS-3c, or STS-12c Synchronous Payload Envelope (SPE). The Hybrid ADM can have low-speed interfaces (e.g., DS1 and DS3) provided by a stand-alone SAM or an integrated SAM. The provisioned bandwidth may be shared among several Hybrid ADMs to provide transport of ATM traffic. In a conventional SONET network, a SONET path provisioned for ATM traffic is used only by the two terminating nodes (i.e., bandwidth provisioned for point-to-point traffic) and is limited to the coarse granularity of the SONET hierarchy (i.e., STS-1, STS-3c, STS-12c). In a Hybrid Ring with Hybrid ADMs, a SONET path provisioned for ATM traffic can be shared among several Hybrid ADMs, with multiple virtual path connections terminating at different nodes, and bandwidth is provisioned on the ring according to the bandwidth needed for a particular VP. This allows better utilization of the provisioned bandwidth for ATM traffic.

Consider, as an example, a SONET OC-12 ring with several 60 Mb/s connections of ATM traffic to a hub.

- In a conventional SONET BLSR or UPSR network, each point-to-point path would require one STS-3c (155.52 Mb/s) to support a 60 Mb/s ATM connection and a switch termination. In this situation, only four paths can be provisioned, with each path utilizing less than 50% of the provisioned bandwidth. Figures 2-23 and 2-24 show in detail the method used for transporting ATM streams on a SONET BLSR and a SONET UPSR, respectively.
- In a Hybrid BLSR or UPSR network, one STS-3c can be provisioned to support two 60 Mb/s ATM connections. This provides higher utilization of the provisioned bandwidth, and allows more nodes to be supported (and thus more customers). Figures 2-25 and 2-26 show two additional nodes being supported on a Hybrid BLSR and UPSR, respectively, compared to the conventional SONET rings shown in Figures 2-23 and 2-24. Assuming all STS-3c paths are reserved for ATM traffic and the same ATM demand (i.e., 60 Mb/s of hubbed ATM traffic at each node) a total of 8 nodes plus the hub node are capable of being supported with an OC-12 Hybrid BLSR or UPSR. For hubbed ATM traffic there are no bandwidth savings when deploying a BLSR as compared to deploying a UPSR. However, for non-hubbed ATM traffic (i.e.,

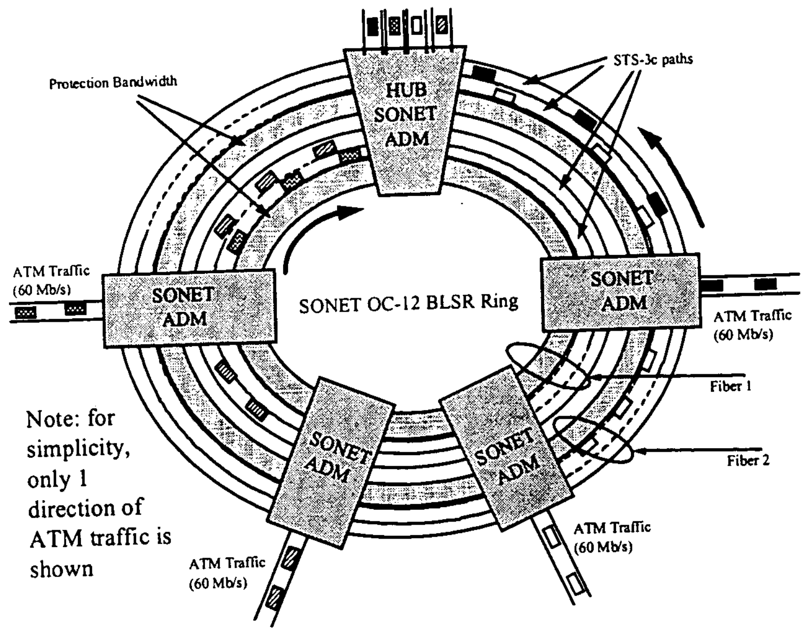


Figure 2-23. Conventional SONET OC-12 BLSR (2-Fiber) - Hubbed ATM Traffic

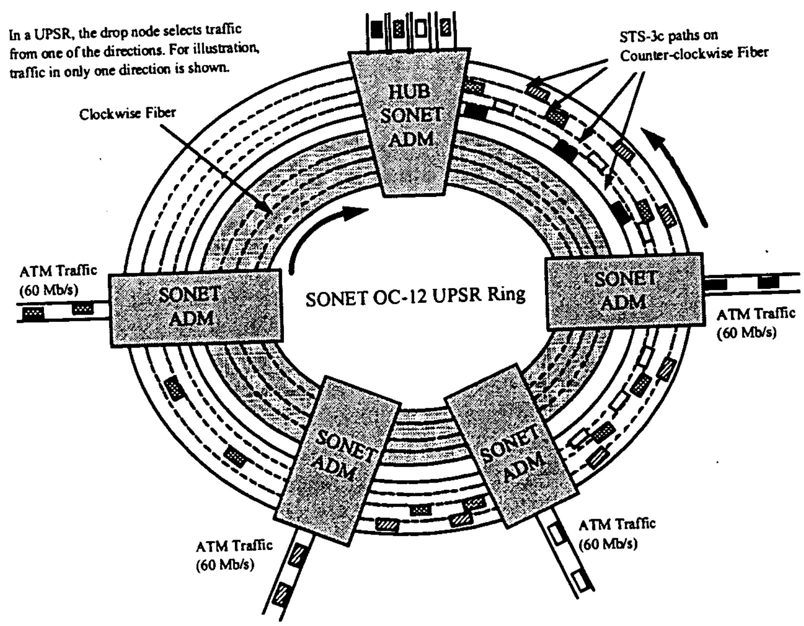


Figure 2-24. Conventional SONET OC-12 UPSR - Hubbed ATM Traffic

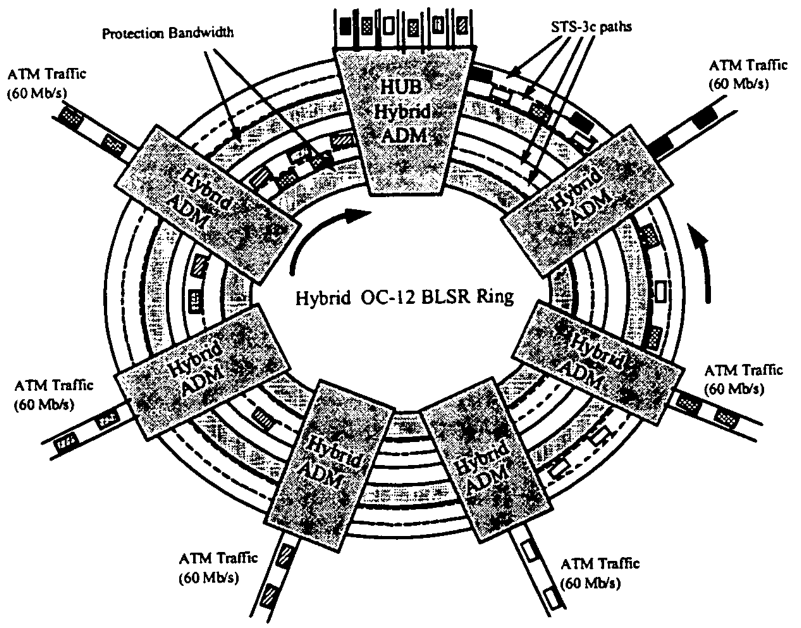


Figure 2-25. Hybrid OC-12 BLSR (2-Fiber) - Hubbed ATM Traffic

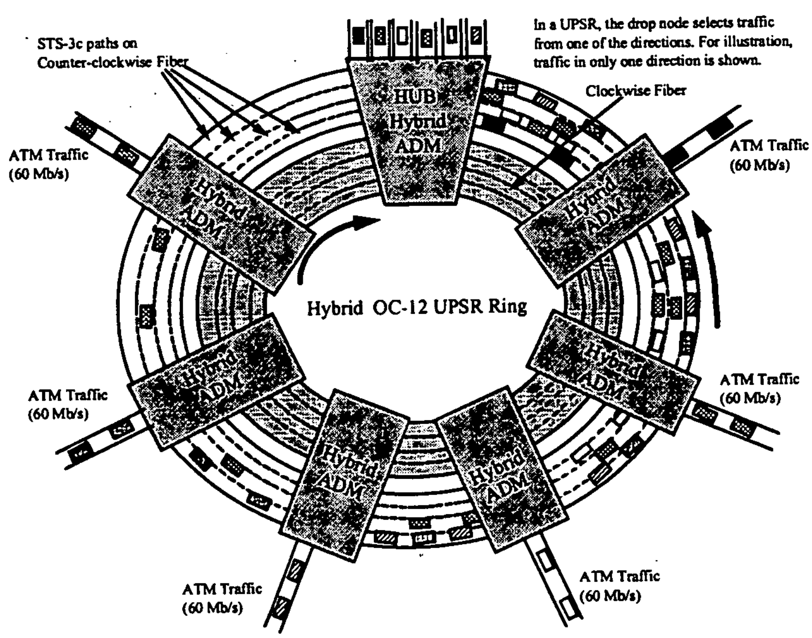


Figure 2-26. Hybrid OC-12 UPSR - Hubbed ATM Traffic

different ATM streams originating and terminating at different ring nodes) the BLSR would have additional bandwidth savings compared to the UPSR.

The above examples describe clearly how Hybrid Ring ADMs can provide better bandwidth utilization for ATM traffic as compared to conventional SONET Ring ADMs.

2.4 Overview of ATM Protection Switching in SONET ATM VP Rings

2.4.1 Ring Types and Protection Types

Six types of SONET rings with ATM VP capabilities have been identified and are listed in Table 2-1. They provide different types of ring functionality and protection switching capability. These six types are in addition to the two types of conventional SONET Rings, the SONET UPSR and the SONET BLSR, not discussed further here.

The Hybrid Ring types provide STM layer protection switching according to SONET Ring protocols, at least for the SONET STM portions, often referred to as self-healing ring characteristics. STM layer protection switching either takes place in the form of path switches (in the UPSR), in the form of ring switches (in the 2-fiber BLSR), or in the form of ring and span switches (in the 4-fiber BLSR). STM layer protection switching has been well established in Standards and in Bellcore GRs (GR-1400-CORE for UPSRs, and GR-1230-CORE for BLSRs). It is very fast, usually restoring traffic within less than 60 milliseconds after the occurrence of a failure. Some Hybrid Rings (Hybrid UPSR and Hybrid BLSR) provide only STM layer protection; they do not provide any ATM layer protection switching. In addition to STM layer protection, other Hybrid Rings (Hybrid VP UPSR and Hybrid VP BLSR) also provide ATM layer protection switching at the VP level.

The pure ATM Ring types (ATM UVPSR and ATM BVPSR) provide only ATM layer protection switching at the VP level. They do not support SONET STM layer self-healing ring characteristics. ATM layer protection switching is still in the process of being defined in standards. Further, Bellcore is currently issuing a GR on ATM layer protection switching, GR-2980-CORE. ATM layer protection switching times have not been explicitly defined. The goal in standards is to be as fast as possible, but the specific protection switching times are still being developed. Input has been requested from the industry in connection with the development of GR-2890-CORE on acceptable ATM protection switching times.

2.4.2 ATM Traffic Protected via STM Layer Protection

In Hybrid Rings of the BLSR type (Hybrid BLSR and Hybrid VP BLSR), ATM traffic can be protected through STM layer protection mechanisms, with some limitations described below. The STM layer protection mechanism has been field proven and has fast protection

switching. The SONET SPE carrying ATM traffic (VPs) is switched to the BLSR's protection channel by the STM layer. When on the protection channel, no ATM processing occurs; ATM processing is only done when the SONET SPE is on the BLSR's working channel.

Among Hybrid Rings of the BLSR type, one can distinguish between rings where VP Identifiers (VPIs) are unique within a VP Connection (VPC) through the ring (i.e., the VPI value remains constant), and rings where the VPIs can change within a VPC through the ring.

In the first case with unique VPIs, the STM layer protection mechanism can also protect ATM VPs, as long as the failure is a line failure, or a node failure that does not involve a source or destination node for the STS signal containing the ATM VP. The latter means that there is no squelching needed for the particular STS signal. However, if the failure is in a node that is a source or destination node for the STS signal containing the ATM VP, the BLSR protocol requires squelching for the affected STS signals in order to prevent STM traffic misconnections, as specified in GR-1230-CORE.

Squelching means replacing traffic by the appropriate path AIS to prevent misconnections. STS level squelching occurs only into and out of the protection channels (i.e., working channels are never squelched). The squelching is done by the nodes performing the ring switching. To perform squelching, the node has to identify the portion of the ring that is isolated due to node failure or multiple failures (causing node isolation). A ring map is needed at each node that includes the order of the nodes (the order of physical connectivity) on the ring. A squelch table that provides the source and destination nodes for each channel (added, dropped, or continued through) and that identifies the channels that are accessed at VT levels (for VT level squelching) needs to be provided. Such squelching would also be effective for ATM VPs and would also prevent ATM traffic misconnections. However, with the existing squelching protocols developed for STM traffic, some good ATM traffic destined to other working nodes may be squelched unnecessarily. Additional ATM squelching protocols need to be developed to avoid squelching of valid ATM traffic.

In the second case without unique VPIs, the STM layer protection mechanism should not be used to protect ATM VPs. The reason for this is that the non-unique VPIs are likely to cause ATM traffic misconnections even for line failures or node failures that do not call for squelching.

In Hybrid Rings of the UPSR type (Hybrid UPSR and Hybrid VP UPSR), ATM traffic cannot be protected efficiently through STM layer protection mechanisms. STM layer protection would be highly impractical in a UPSR because ring wide 1+1 STM layer protection would rapidly consume the bandwidth of a UPSR. This is because each STS-Nc span over which ATM cells are transported would have to be duplicated with a protection path in the opposite direction around the ring to protect against facility failures. The result would be an increase in the required ring bandwidth proportional to the number of STS-Nc connections. The resulting excessive bandwidth required would have major cost implications. Furthermore, even if this excessive bandwidth were implemented, adequate

protection of failures of nodes that involve pass-through ATM traffic would not be possible. For these reasons, STM layer protection for ATM traffic in UPSRs is not recommended.

2.4.3 ATM Traffic Protected via ATM Layer Protection

A more robust method of protecting ATM traffic in Hybrid Rings would be to exclusively use ATM layer protection for ATM traffic. At the same time, STM layer protection should be disabled for those STS signals that are designated to carry ATM cells. This would make STM layer protection and ATM layer protection independent from each other and would also eliminate the need to specify escalation procedures between the two layers.

Standards work has progressed in defining 1+1 and 1:1 ATM point-to-point protection mechanisms. The definition for 1:n ATM point-to-point protection is left for future study. Agreements were reached to initially support 1+1 and 1:1 bidirectional protection switching over fully allocated paths and bandwidths, under the control of a single phase coordination protocol. The ITU-T agreement targets the ATM protection domains as being defined between any two ATM nodes within the connection. This will allow arbitrary nesting of protection spans. GR-2980-CORE covers ATM layer point-to-point protection switching in detail for linear, mesh, and ring physical topologies.

These ATM point-to-point protection mechanisms can be applied to Hybrid Rings and pure ATM Rings. See Section 4.3.2 for specific ATM protection switching requirements. It is feasible to use the defined ATM layer protection switching while disabling the STM layer protection on those STS signals that are designated to carry ATM cells. STM layer protection will continue to protect those STS signals that carry STM traffic.

2.4.4 ATM Traffic Protected Externally

As can be noted from Table 2-1, the Hybrid UPSR does not provide any protection for ATM traffic. STM layer protection in a UPSR is not feasible for ATM traffic as explained in Section 2.4.2. However, ATM traffic may be protected externally by ATM NEs outside the ring. Figure 2-27 shows a Hybrid UPSR with two external ATM NEs. In this example, Nodes A and B are the only nodes on the ring adding and dropping ATM traffic. At Node C, the STS path carrying ATM is through-connected. The UPSR self-healing ring functionality (the STM layer protection) is disabled for the STS carrying ATM traffic at every node that adds and drops ATM traffic, i.e., at Nodes A and B. ATM cell traffic entering the ring at Node A is routed to the appropriate VP within the designated STS (only one direction is shown). There is both a working VP bandwidth and a protection VP bandwidth available and each could be assigned different VPI values. Normally, only cells with working VPI value enter the ring. A failure occurring anywhere on the ring would eventually be detected by the ATM NEs off the ring. The ATM NEs off the ring would then begin to send cells in the protection VP bandwidth (i.e., using protection VPI value).

Therefore, both a working VP and a protection VP are not simultaneously dropped at A and B. This option can be viewed as 1:1 ATM protection. In the architecture shown in Figure 2-27, the ATM services would be susceptible to failures of the links connecting the ATM NEs with the ring. To provide self healing for these links as well, the ATM nodes could be dual homed on the ring (as shown in Figure 3-14).

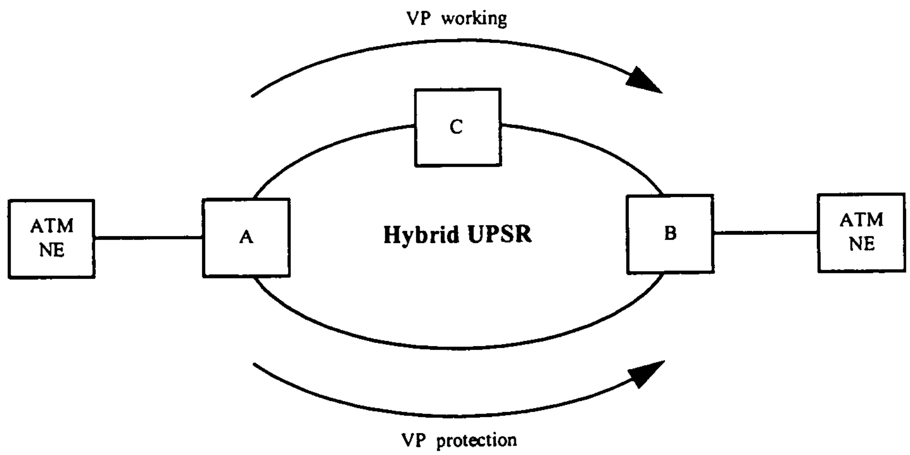


Figure 2-27. Hybrid UPSR with ATM Protection off the Ring

2.5 Ring Interconnection Overview

Dual-node ring interconnection is the method used to provide highly reliable interconnection between conventional SONET Rings and other networks, including other SONET Rings and mesh networks. This method provides the same kind of survivability and self-healing capability for interring circuits as the individual rings provide for intraring circuits. Dual-node interconnections can survive a failure of an interconnecting node or an interconnecting link. Both the UPSR and BLSR utilize a 1+1 protection scheme when providing dual-node ring interconnection. Methods for dual-node ring interconnection have been standardized for conventional SONET UPSR and BLSR architectures and are documented in GR-1400-CORE and GR-1230-CORE, respectively.

Dual-node ring interconnection between two SONET UPSRs is shown in Figure 2-28. Only one direction of transmission is shown, with a path from an origination node on Ring 1 to a destination node on Ring 2. A drop-and-continue function and a selection function at the exit nodes of Ring 1 select the better of the two signals (from the working ring and the protection ring) to be dropped and provide a duplicate copy of the signal at two exit nodes. These duplicate signals enter Ring 2 at the two entrance nodes. One of the duplicate signals is added to the working ring and the other one to the protection ring. At the destination node, a selection function selects the better of the two signals and delivers it to the drop

port. The drop-and-continue and the selection functions operate at the STM level, i.e., they operate on STS or VT path level signals.

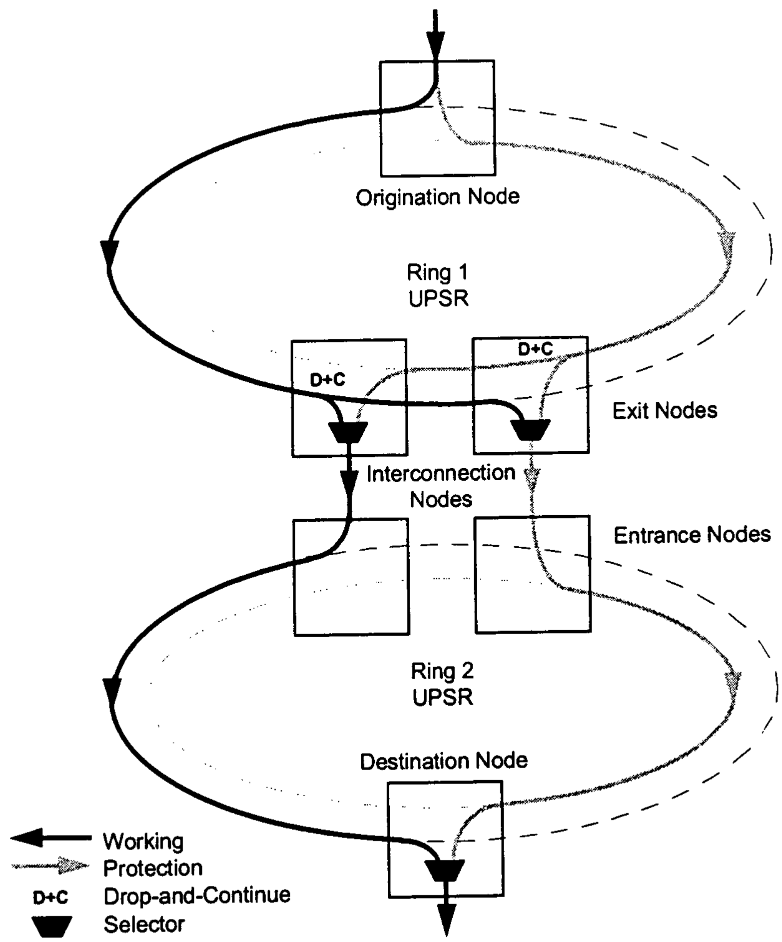


Figure 2-28. Dual-Node Ring Interconnection Between SONET UPSRs

Dual-node ring interconnection between two SONET BLSRs is shown in Figure 2-29. Again, only one direction of transmission is shown, with a path from an origination node on Ring 1 to a destination node on Ring 2. A drop-and-continue function at the exit nodes of Ring 1 provides a duplicate copy of the signal at two exit nodes. These duplicate signals enter Ring 2 at the two entrance nodes. A selector function at the primary entrance node selects the primary signal (black line) under normal conditions, or the secondary signal (gray line) coming from the secondary entrance node under failure conditions, to proceed within the ring to the drop port at the destination node. The drop-and-continue and the selection functions normally operate at the STS-1 line level.

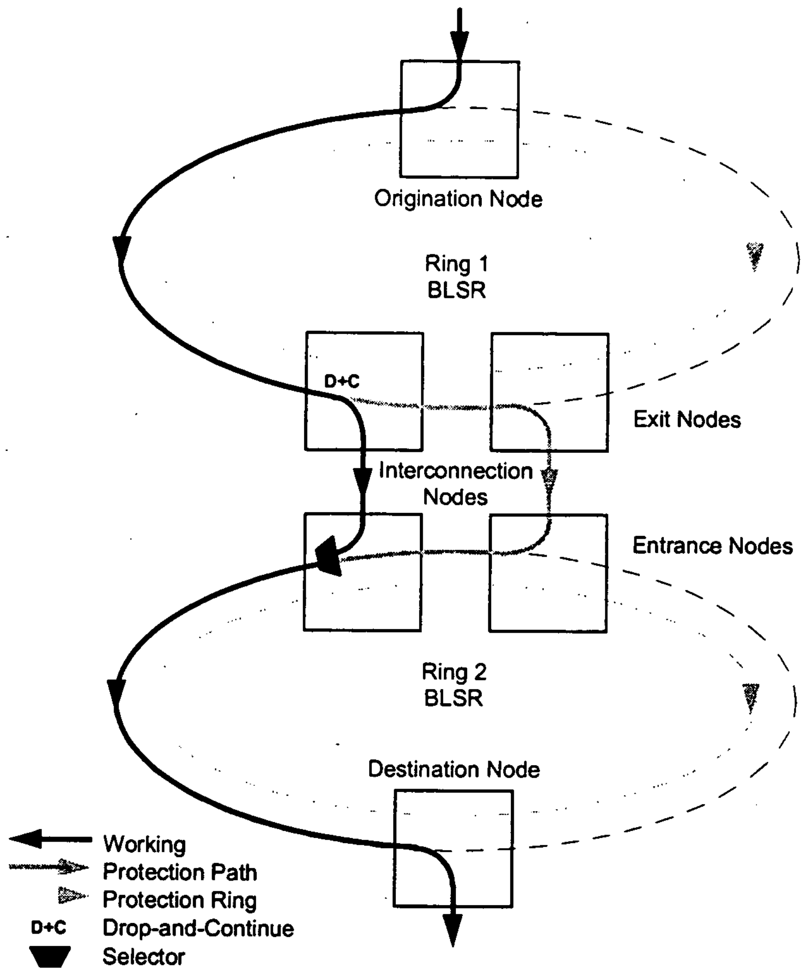


Figure 2-29. Dual-Node Ring Interconnection Between SONET BLSRs

Similar ring interconnections between SONET UPSRs and SONET BLSRs are possible, using the UPSR method shown in Figure 2-28 on the UPSR side and the BLSR method shown in Figure 2-29 on the BLSR side.

In SONET BLSRs, squelching is applied to some signals in the case of failures of the signals' source or destination nodes, in order to prevent traffic misconnections. Dual-node ring interconnections are covered by the same squelching logic when applied to multiply dropped and multiply sourced signals. The term "multiply dropped" here relates to the drop-and-continue function that drops duplicate signals at the two interconnecting ring nodes. The term "multiply sourced" here relates to the duplicate signals entering the ring at the two interconnecting ring nodes. The squelching logic is described in GR-1230-CORE.

As SONET ATM VP Rings become more prevalent in service provider networks it will become necessary to provide a reliable means of interconnecting such rings to other networks (e.g., SONET Rings, other SONET ATM VP Rings, and mesh networks). This type of ring interconnection is similar to that used for the interconnection of pure SONET Rings.

Since Hybrid Rings perform both SONET and ATM layer functions, the options of performing the drop-and-continue function and the selector function at the SONET or ATM layer are available. For pure ATM Rings, these functions are always performed at the ATM layer. Further, for the Hybrid BLSR and the Hybrid VP BLSR, the potential for carrying ring interconnection traffic on STM protection bandwidth is available. BLSR protection bandwidth is unused in nonfailure situations. This capability is similar to the Ring Interworking on Protection bandwidth (RIP) which has been specified for SONET BLSRs. More efficient and flexible use of ring bandwidth can be obtained with RIP, but there are complexity issues for the secondary ring interconnection node (requires enhanced functionality), and issues with reliability of certain intraring traffic as well as possible misconnections of intraring traffic.

For STM traffic, existing SONET ring interconnection methods can be used. For ATM traffic, similar methods could be employed, and are yet to be defined. For example, interconnection at the ATM layer between two ATM UVPSRs could be modeled after the interconnection between two SONET UPSRs, as done in Figure 3-9.

Each of these options needs to be addressed with respect to the following criteria: bandwidth efficiency, reliability/survivability, bandwidth management, and standards compliance.

The development of SONET ATM VP Rings is still in its early stages. This GR provides initial requirements for ring interconnections on such rings. Protection schemes need to be defined for the ATM layer between interconnected rings. Since SONET Rings (UPSR and BLSR) utilize a 1+1 protection scheme for dual-node ring interconnection, SONET ATM VP Rings will have to utilize the same scheme in order to ensure interworking between the two types of rings.

3. Network Applications

This section describes some potential network applications for SONET ATM VP ADMs. A number of ring applications are shown first, because self-healing ring architectures are currently dominant in existing SONET networks and can provide high survivability, as discussed in Section 2.2.2.1. Many applications shown involve Hybrid Rings (i.e., SONET Rings that include ATM VP functionality) that are part of Hybrid networks. Since these rings carry a mixture of non-ATM and ATM traffic, the ADMs on the rings may be a mixture of pure SONET Ring ADMs and Hybrid Ring ADMs, as shown. Other applications involve pure ATM Rings. In addition to ring applications, other potential applications in hub and mesh architectures are described, as well as ring-to-mesh interconnections.

3.1 Access Rings

Access rings are usually placed close to a community of customers and serve the purpose of interconnecting customers within that community and collecting traffic from customers in that community for connection to more distant locations, through local offices to interoffice or backbone networks. As customers start demanding ATM connections, even in moderate numbers, it becomes more efficient to introduce Hybrid Rings as access rings, as explained in Section 2.3. Figure 3-1 illustrates an access Hybrid Ring with a variety of NEs. The Hybrid Ring can be populated with SONET ADMs, Hybrid ADMs, and Hybrid ADMs with integrated SAM functionality. Stand-alone SAMs and Edge Switches (ESs) may also be part of the access network. All of these NEs work together to provide an efficient fill of ATM traffic on the access ring, which then can be handed over to the BSS and/or the interoffice network.

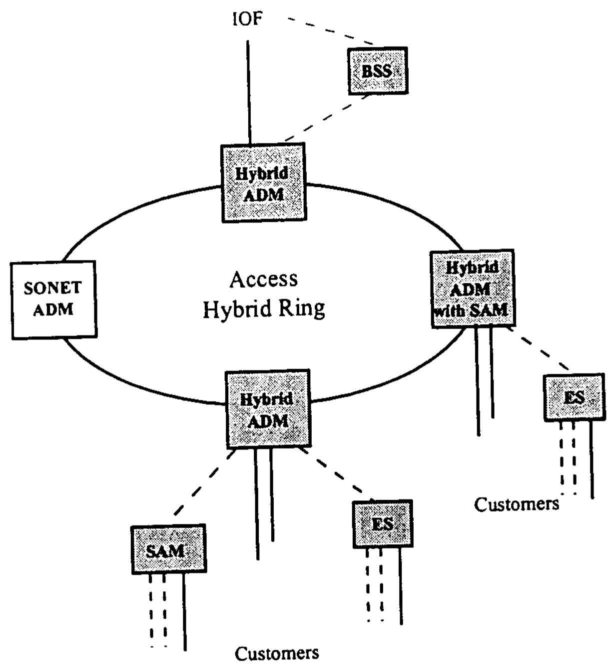


Figure 3-1. Access Hybrid Ring

3.2 Interoffice Rings

Interoffice rings usually provide transport for trunks between offices. They mostly connect to switches in those offices (BSSs for ATM cell switching, and local or tandem digital switches for circuit switching). They may also connect directly to access rings for direct trunks and private (unswitched) line connections. Further, they may provide connections to backbone networks and also between different carriers or service providers. Transporting a moderate amount of ATM traffic does not necessarily require the conversion from SONET to Hybrid Rings for interoffice rings. The latter can well be SONET Rings, transporting ATM efficiently over conventional SONET ADMs (using Technique 1 in Figure 2-1), as long as the ATM traffic is efficiently filled into the SONET STM payload by the access network, and as long as the number of different ATM connections on the ring is small. With increased ATM demand with many ATM entry and exit points on the ring, it becomes more efficient to introduce Hybrid Rings as interoffice rings. Figure 3-2 illustrates an interoffice Hybrid Ring with a variety of NEs. The Hybrid Ring can be populated with SONET ADMs and Hybrid ADMs. The Hybrid ADMs allow efficient sharing of ring bandwidth between many ATM connections.

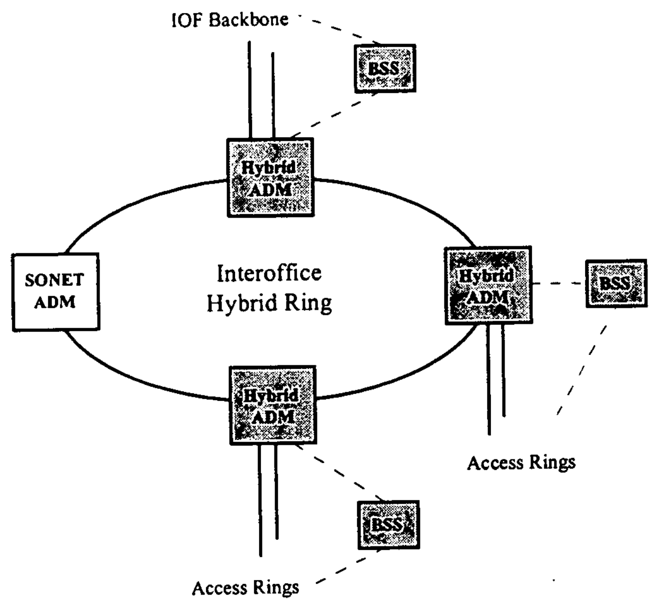


Figure 3-2. Interoffice Hybrid Ring

3.3 Interconnected Rings

Rings can be interconnected in many different ways. Section 3.3.1 introduces the most common basic interconnections employed. Section 3.3.2 illustrates examples of some specific applications for ATM traffic.

3.3.1 Basic Interconnections

Rings can be interconnected directly by interconnecting low-speed ports of the Hybrid ADMs, as shown in Figure 3-3, or they can be interconnected indirectly through Hybrid DCSs, as shown in Figure 3-4. The Hybrid DCS can provide grooming and consolidation functions between the rings. A much more powerful application is the use of Hybrid DCSs with ring functionality as ring interconnection nodes, as shown in Figure 3-5. This application uses the capability of such DCSs to provide ring transport functions for more than one Hybrid Ring.

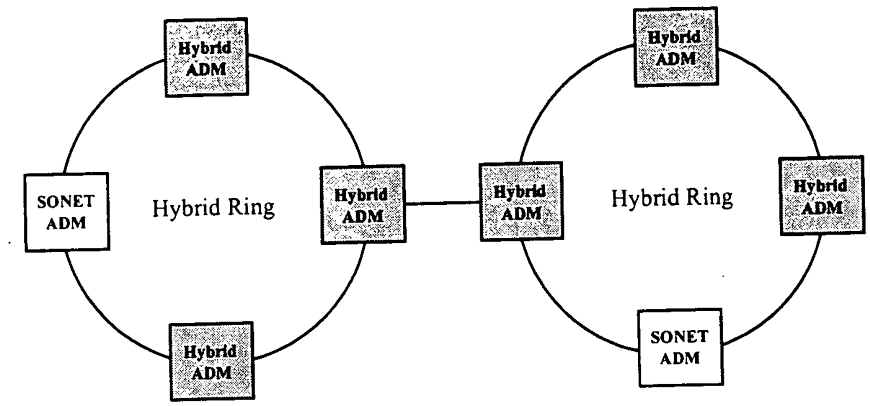


Figure 3-3. Direct Ring Interconnection Between ADMs

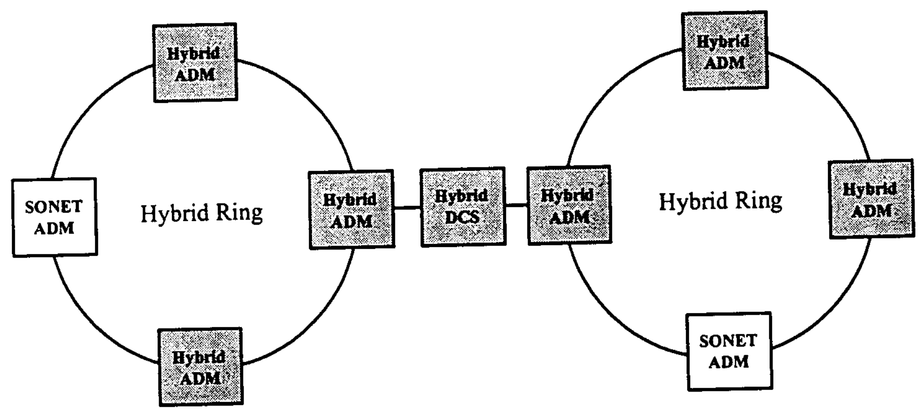


Figure 3-4. Ring Interconnection Between ADMs Through DCS

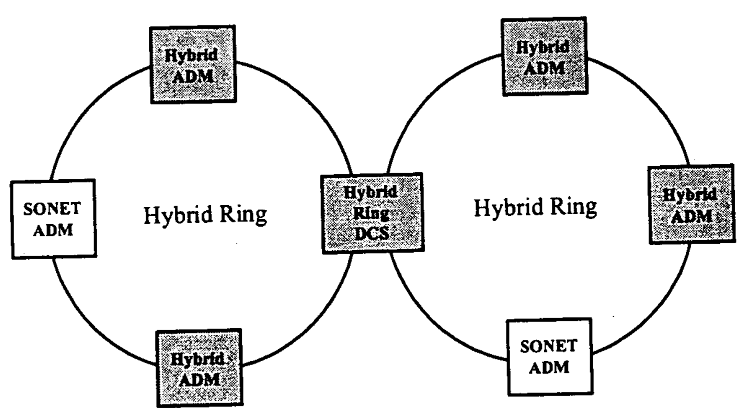


Figure 3-5. Ring Interconnection Through Ring DCS

Although single-node ring interconnection is feasible, dual-node ring interconnection is the preferred method when a high level of survivability is required. This method is also referred to as "dual homing." Figures 3-6, 3-7, and 3-8 show the dual-node interconnections corresponding to the three single-node interconnections above.

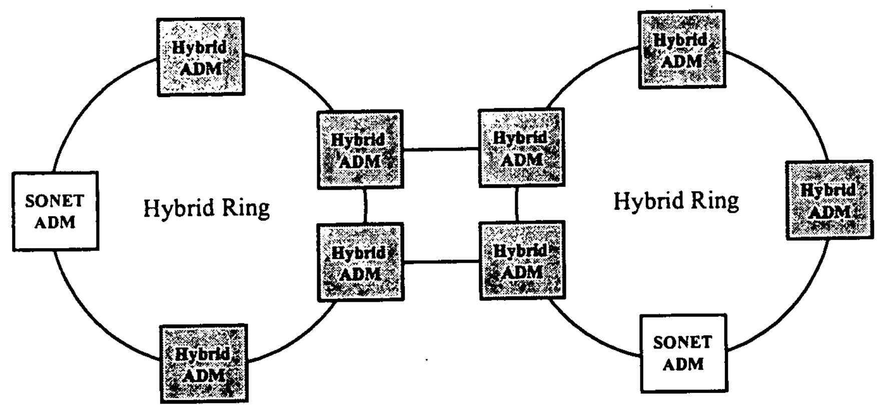


Figure 3-6. Direct Dual-Node Ring Interconnection Between ADMs

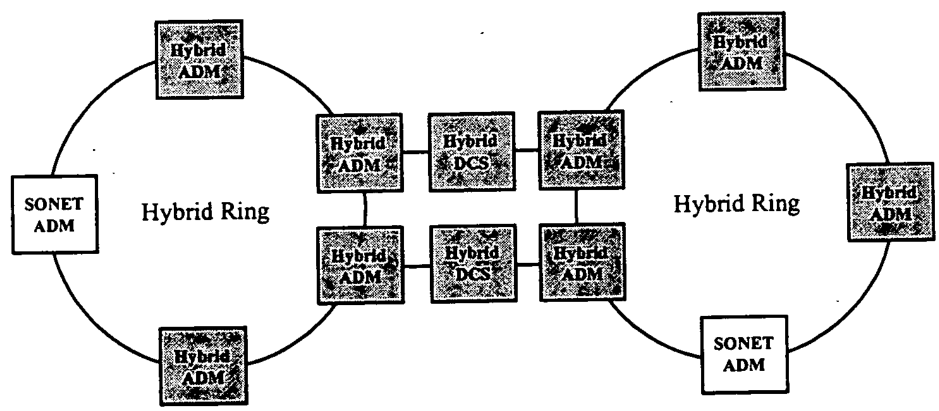


Figure 3-7. Dual-Node Ring Interconnection Between ADMs Through DCS

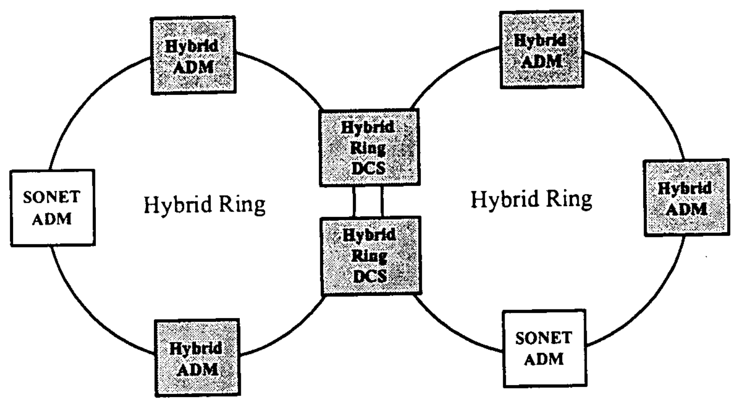


Figure 3-8. Dual-Node Ring Interconnection Through Ring DCS

3.3.2 Specific ATM Ring Interconnection Applications

This section illustrates examples of ring interconnections involving pure ATM Rings, in particular ATM UVPSRs, and logical rings with SONET ATM VP Rings connecting to SONET Rings.

3.3.2.1 Interconnections Between Pure ATM Rings

An ATM UVPSR to ATM UVPSR interconnection for ATM traffic can be achieved by using dual-node interconnection or single-node interconnection. In either case, the ATM user traffic passed between the interconnected rings is based on VP connections. The dual-node ring interconnection mechanism is shown in Figure 3-9.

As can be seen from the figure, two NEs in each ring are involved in the ring interconnection. A 1+1 protection scheme is used at the ATM VP layer, modeled after the 1+1 protection scheme at the STM layer in interconnected SONET UPSRs (see Figure 2-28). The drop-and-continue function provides a duplicate copy of the signals leaving a ring at the two interconnecting nodes. The routes of VPs from one ring to the other ring are shown by solid lines. For a VP from one ring to the other ring, the egress traffic on the first ring is selected from the traffic flows from both directions of that ring at the VP level, so that any fault or defect in the first ring will not affect the second ring. Because of the dual-node interconnection, a failure of a single ring interconnection NE or a single link between the two rings will not separate the two interconnected rings. Only the traffic flows to be delivered to the other ring are dropped at the ring interconnection interface and the rest of the traffic (shown as a dashed line) is continued and merged with the incoming traffic from the other ring. The ring interconnection interface between the two rings can be any ATM interface. In each ring interconnection NE, the ingress traffic on the ring interconnection

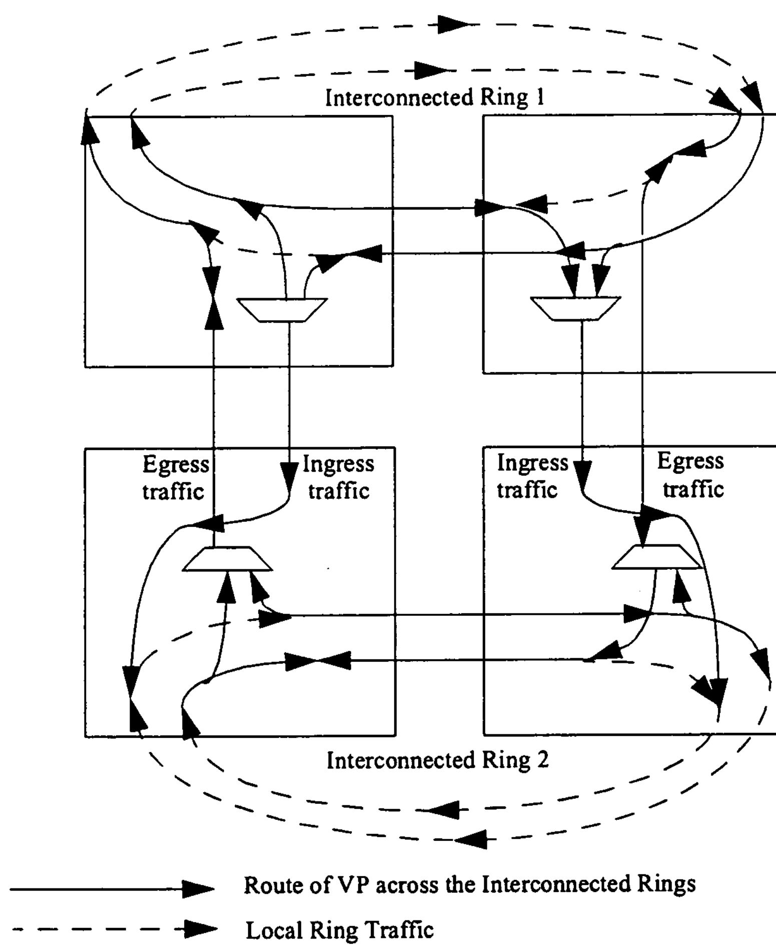


Figure 3-9. Dual-Node Ring Interconnection Between ATM UVPSRs

interface is only added onto one direction of the ring. The two NEs add the traffic to the opposite directions on the ring. At the destination node of an ATM VP path on the second ring (not shown in the figure), another selector function selects the better of two signals from both directions.

Figure 3-10 shows another type of ATM UVPSR ring interconnection that is basically a single-node interconnection but uses a SONET 1+1 facility protection interface. This is the type of interface that is normally used to drive a 1+1 protected facility from a low speed port of a ring ADM, providing facility protection switching at the SONET STM layer. However, here it is used to provide a single-node, dual-link interconnection between two rings. In the egress direction, a drop-and-continue function and two selector functions are shown, providing duplicate signals to the other ring. Another alternative would be use a

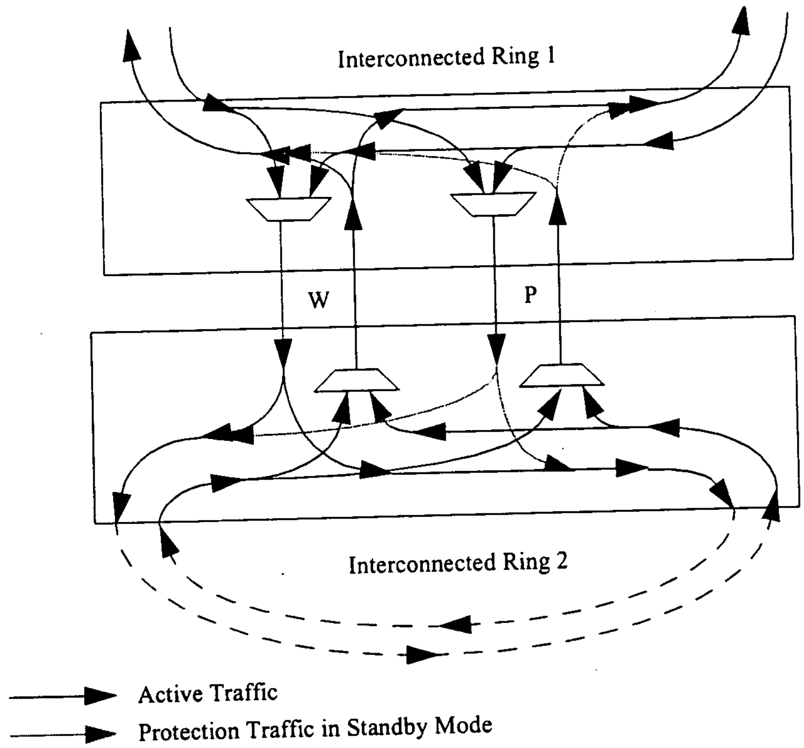


Figure 3-10. Single-Node Ring Interconnection with 1+1 Ring Interconnection Interfaces

single selector function followed by a double feed. This type of ring interconnection provides protection against a link failure or selector failure, but not against a node failure. As shown in Figure 3-10, only the working ring connection interface (W) adds the traffic onto the other ring. The protection ring connection interface (P) carries the same traffic as the working interface but does not add the traffic onto the other ring under normal operating conditions without failures. A selector function in the ingress direction (not shown) will select the traffic from the protection interface in case of a failure of the working interface.

Figure 3-11 shows how a ring NE can be involved in more than one ring interconnection. The figure shows three interconnected ATM UVPSRs. NE1 in Ring 1 is involved in two ring interconnections, connecting to Ring 2 and Ring 3. This is a new type of NE with multiply dropped ring interconnection capability within a single NE. NE1 serves as one of the dual nodes with NE2 and NE3, to form dual-node ring interconnections between Rings 1 and 2 and between Rings 1 and 3, respectively. In NE1, the traffic of the VPs destined to Rings 2 and 3 is dropped at the corresponding ring interconnection interfaces to NE5 and NE6. The latter two interfaces carry different sets of VPs (the two sets are disjoint). The traffic of the VPs arriving from Rings 2 and 3 is added to the corresponding direction of Ring 1 in NE1.

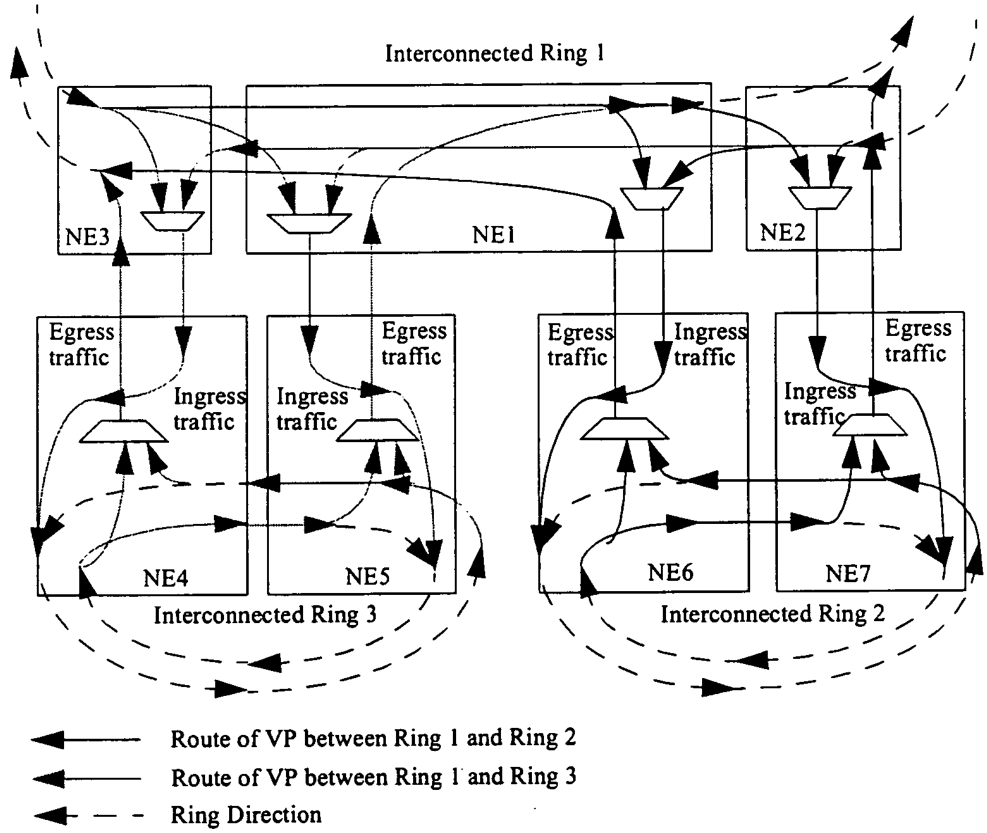


Figure 3-11. Dual-Node Ring Interconnection Between ATM UVPSRs - One NE Serving more than One Ring Interconnection

Figure 3-12 shows a unidirectional point-to-multipoint (i.e., multicast) connection that extends over three ATM UVPSRs. This figure is very similar to Figure 3-11, where NE1 in Ring 1 is involved in two ring interconnections, connecting to Ring 2 and Ring 3. It shows the VP multicast route with traffic originating in Ring 1 at the VP source point. Rings 2 and 3 are the traffic receiving rings with VP destination points of the multicast. The only difference from Figure 3-11 is the unidirectional traffic and the fact that the two interfaces to Rings 2 and 3 carry the same set of VPs (the two sets are common).

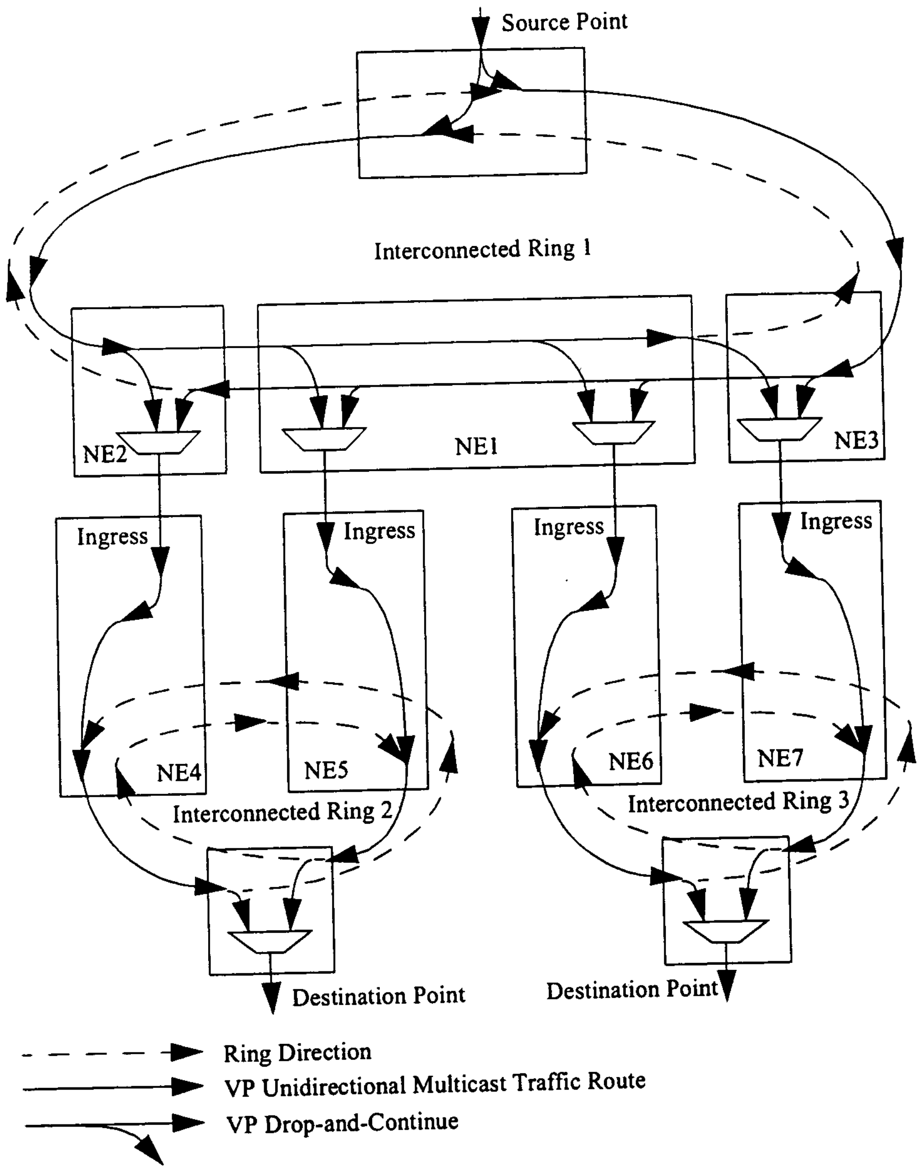


Figure 3-12. VP Multicasting in Dual-Node Ring Interconnection Between ATM UVPSRs

3.3.2.2 Logical Ring Interconnection

In general, a SONET ATM VP Ring to SONET Ring interconnection is at the SONET path level (e.g., STS or VT). However, a SONET ATM VP Ring to SONET Ring interconnection can be viewed in a layered network concept. An intermediate SONET Ring can be viewed as being transparent to the SONET ATM VP Ring passing through it.

Figure 3-13 shows a SONET Ring in the middle of a SONET ATM VP Ring in a logical ring configuration. The SONET ATM VP Ring may be a pure ATM Ring or a Hybrid Ring. On the SONET Ring, one of the SONET STS signals (STS-1 or STS-Nc) is used for the SONET ATM VP Ring to traverse the SONET Ring. This STS signal must be provisioned as an intraring connection on the SONET Ring to ensure connectivity when a protection switch takes place on the SONET Ring. At the ATM layer, the SONET Ring can be viewed by the SONET ATM VP Ring passing through it as being a transparent SONET link. The interface to the SONET Ring is an STS signal (STS-1 or STS-Nc). In general, the SONET path overhead is only modifiable by path terminating equipment. Since the SONET ADMs in the SONET Ring are not path terminating equipment, the path overheads, e.g., the path traces, of the signals traversing the SONET Ring are not changed by the SONET ADMs.

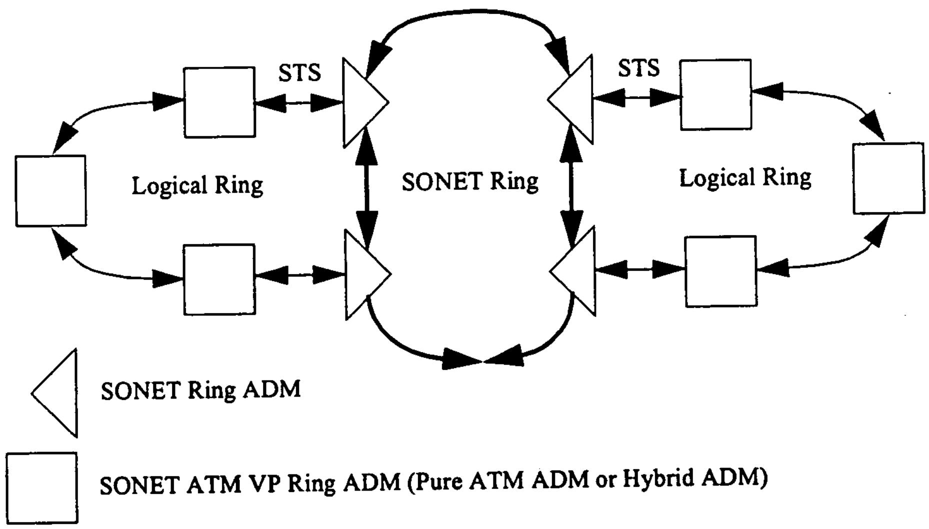


Figure 3-13. SONET ATM VP Ring to SONET Ring Interconnection

3.4 Point-to-ADM, Dual Homing

A point located off a ring can be connected to the ring via single homing or dual homing. The latter, shown in Figure 3-14, provides a higher level of survivability by protecting from link and ring node failures. Similar to dual-node ring interconnections, the two connecting

nodes on the ring provide the drop-and-continue and selector functions. The Terminal Multiplexer (TM) off the ring needs to provide dual feed and selector functions. This arrangement applies to SONET as well as Hybrid NEs.

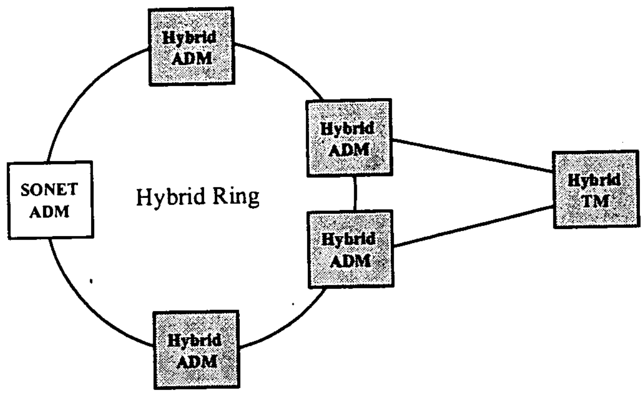


Figure 3-14. Point to ADM, Dual Homing

3.5 Ring Hierarchies

Large networks with a large number of rings can be organized in a hierarchical manner. Access rings represent the lowest level, and interoffice and backbone rings populate the higher levels, as shown in Figure 3-15. Higher level rings extend over a larger area and can also be viewed as express rings, with a number of subtending rings. Again, the dual-node ring interconnection is preferred for high survivability.

3.6 Hubbing via Ring

In future stages of ATM deployment, a highly survivable hubbing structure could be established by employing a Hybrid Ring to connect multiple locations to a BSS hub. Such a ring is shown in Figure 3-16; it provides optical links between the hub BSS with optical OC-N interfaces and Hybrid ADMs as well as Hybrid Ring DCSs. In this example, the ring may carry ATM traffic only.

All nodes on the ring, including the BSS, have self-healing ring functionality[1] of the BLSR type. By employing unique VPIs, ATM traffic can be protected through the STM layer protection mechanism as described in Section 2.4.2. As a result, all the benefits of Hybrid Rings apply, including the high survivability provided by the standard STM ring physical

1. The current BSS requirements do not include ring functionality. Self-healing ring protection functionality would have to be added to the BSS to allow its use as described in this section.

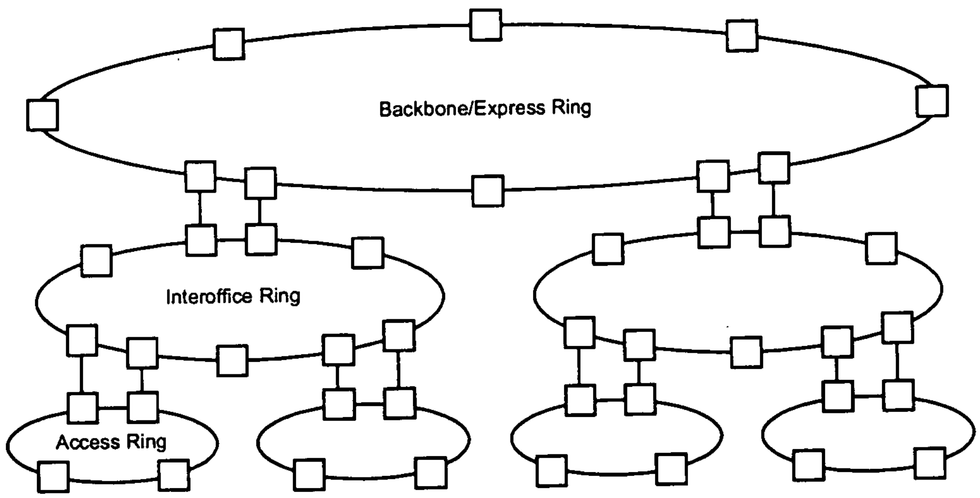


Figure 3-15. Ring Hierarchy

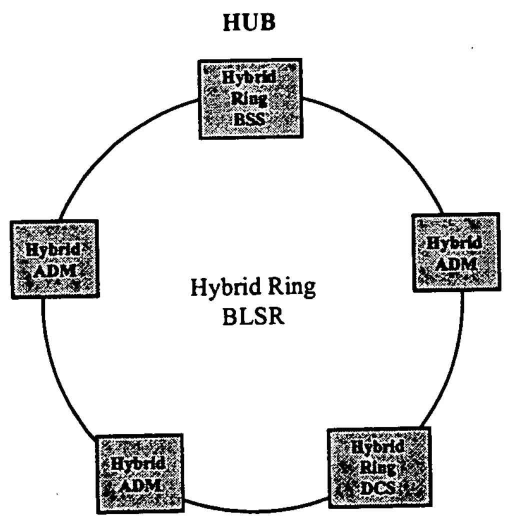


Figure 3-16. Hubbing Via Hybrid Ring

layer protection with its inherent fast restoration time of not more than 60 milliseconds (consisting of a failure detection time of not more than 10 milliseconds and a protection switching time of not more than 50 milliseconds).

3.7 Ring-to-Mesh Interconnection

It is likely that some SONET ring networks will be connected to SONET mesh networks, especially between different carriers that may employ different architectures. With the introduction of ATM, this may be extended to Hybrid networks. Similar to interconnecting rings, a single node or a dual node interconnection can be employed, the dual node approach giving a higher survivability level. Figure 3-17 shows a dual node interconnection between a Hybrid Ring and a Hybrid Mesh architecture. Two Hybrid ADMs on the ring provide the dual node interconnection to two Hybrid DCSs in the mesh network. To provide a seamless interconnection between the ring and the mesh that requires no inter-network signaling for interworking or to effect restoration in either network, the two interconnecting Hybrid DCSs on the mesh side must also have basic ring functionality (drop-and-continue and selector functions). This configuration is well suited to interconnect two networks belonging to different carriers. It establishes a distinct administrative boundary off the ring and off the mesh.

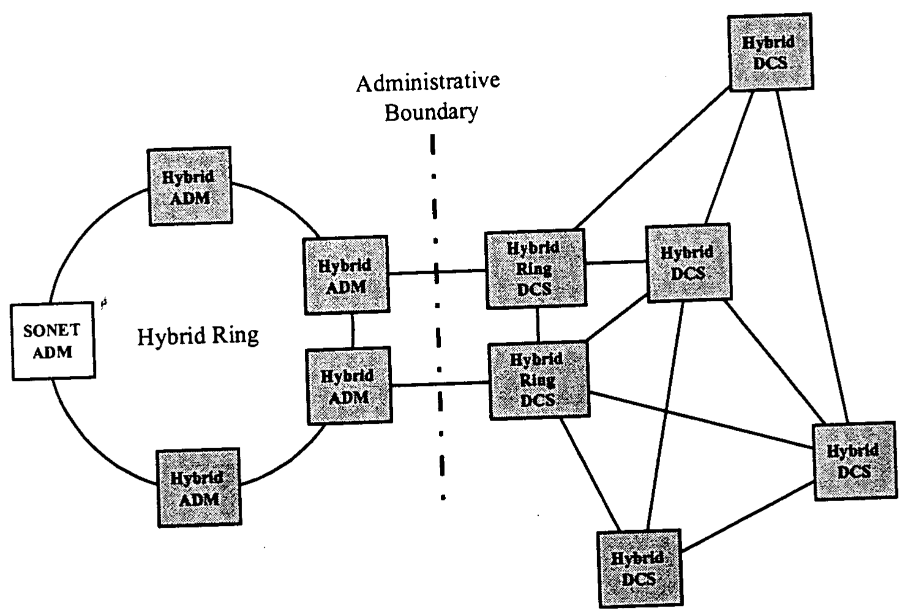


Figure 3-17. Ring-to-Mesh Interconnection, with Distinct Boundary

If no such boundary is required, the ring and mesh network may be directly interconnected through two Hybrid Ring DCSs, as shown in Figure 3-18. The Hybrid Ring DCSs are part of the ring as well as part of the mesh network, and thus must have ring functionality as well as mesh restoration capabilities.

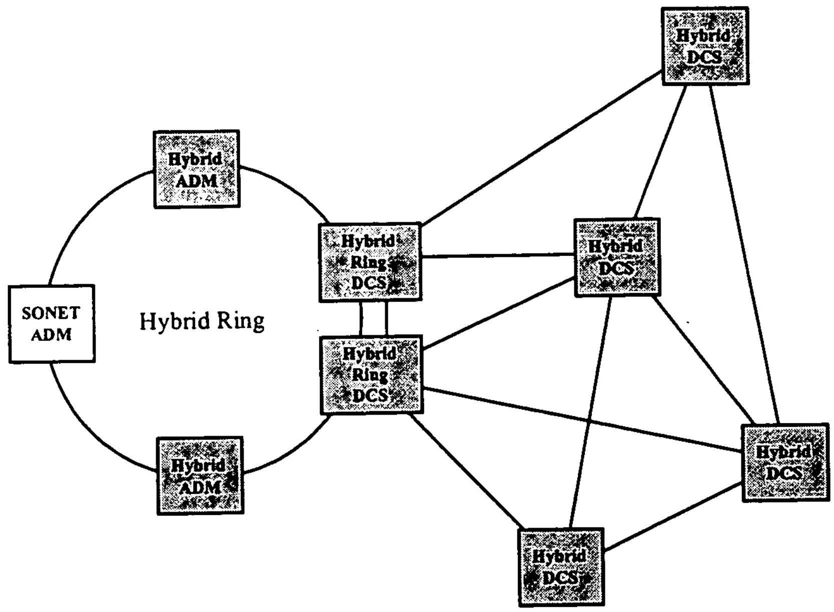


Figure 3-18. Ring-to-Mesh Interconnection

4. Common ATM Transport Functionality and Criteria

This section provides ATM criteria that are independent of ring type. The functional model presented in this section is the first step in a movement toward the modeling methodology of ITU-T G.805 and I.326 with the goal of aligning with the requirements of ITU-T I.731 and I.732. Operations requirements are presented in Section 5. The goal there is also to align with Layer Management functions in I.732. Network traffic management requirements can be found in Section 5.3.

The introduction of the ATM VP functionality into the SONET ring ADM should not impact the STM functionality of the SONET "layer" of the Hybrid ring or pure ATM ring.

R4-1 [1] All transport requirements for the SONET layer found in GR-1400-CORE, GR-1230-CORE, and GR-253-CORE must be followed for Hybrid ADMs, where applicable.

4.1 High-Level Functional Models

Two high-level functional models of Hybrid ADMs are presented below: a basic functional model without SAM functions and a functional model with SAM functions. The SAM function allows direct service access interfaces to the Hybrid ADM.

4.1.1 Basic Functional Model

Figure 4-1 shows a high-level functional model of a Hybrid ADM. Traditional STM traffic is processed at the STM level using the existing functionality of SONET ADMs while some portion of the ring bandwidth (e.g., STS–3c) is shared, processed, and managed at the ATM layer by the ring nodes with ATM functionality. The ATM processor provides ATM VP add/drop functions. Add/drop is thus provided for both STM and ATM services. Note: The timing mode for the Hybrid ADM (not shown) uses the same timing functions established for the STM processor to synchronize all equipment interfaces.

R4-2 [2] The timing mode for the SONET ATM VP ring node shall use the same timing functions (as given in GR-253-CORE) established for the STM processor (or equivalent) to synchronize all equipment interfaces.

The timing functions are synchronized to a clock source (i.e., external timing from BITS, incoming line, or internal). A SONET ATM VP ring node, for example, may use internal Stratum 3 or 3E timing. In end-to-end VCCs, timing information is passed between the source and destination to allow clock recovery at the receiving end. A timing recovery option may depend on the SONET ATM VP ring node timing being traceable to a Primary Reference Source (e.g., for CES).

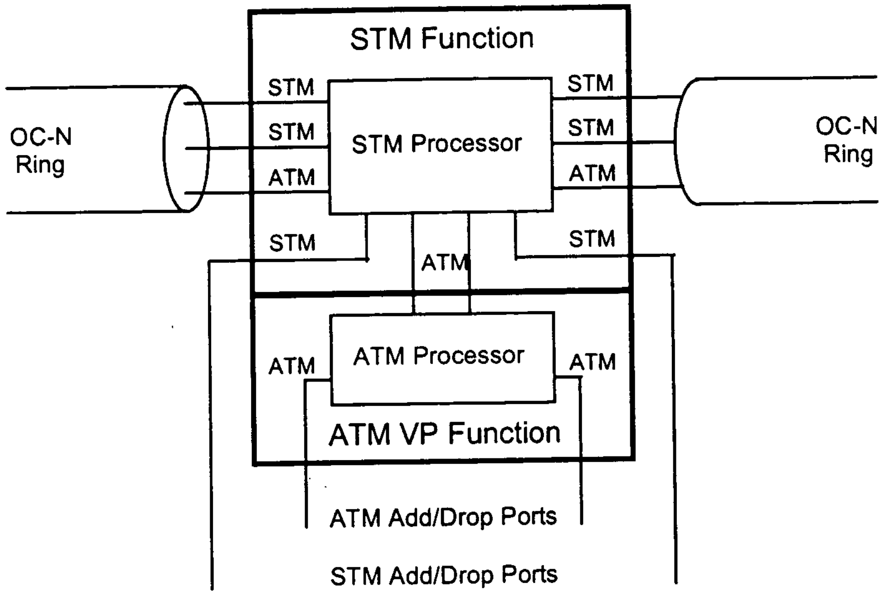


Figure 4-1. Basic Functional Model of ATM Functionality Being Added to SONET Ring ADM

The common functional criteria specified in this GR are believed to be the minimum amount (and presumably the most cost effective) of ATM VP functionality for a SONET ADM to operate as a SONET ATM VP ring node. Although the vision in this GR is for a SONET ATM VP ring node with limited ATM VP functionality and with signaling tunneling capability for use in SVC networks, this does not preclude suppliers from adding ATM functionality to SONET ATM VP ring ADMs beyond that specified in this GR; however, the requirements of GRs that cover these additional functions shall still be met.

CR4-3 [3] If the ATM functionality added to a SONET ring ADM has unrestricted ATM switching connectivity across all interfaces (VPI, VCI based connectivity) and supports SVCs (with signaling capability), then the ATM functionality shall meet the requirements of GR–1110–CORE.

CR4-4 [4] If the ATM functionality added to a SONET ring ADM is intended to provide ATM VP cross-connection functions, then the ATM functionality shall meet the ATM VPX functionality requirements of GR–2891–CORE.

4.1.2 Functional Model with SAM Functions

Figure 4-2 shows a high-level functional model of a Hybrid ADM with integrated SAM functions. The SAM function provides multiplexing and adaptation (including AAL) for a variety of service interfaces. These service access interfaces may include ATM CRS, FRS, LAN, XDSL, SMDS, DS1/DS3 CES, video, etc. All of these interfaces or only a subset of them may be implemented.

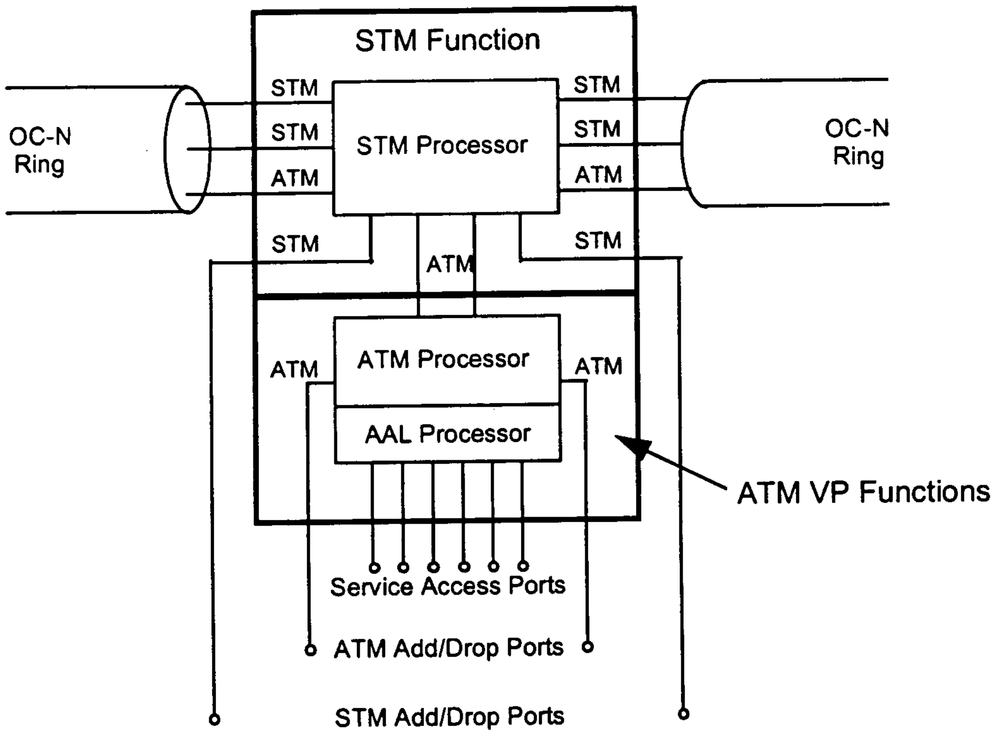


Figure 4-2. Basic Functional Model of ATM Functionality with SAM Functions Being Added to SONET Ring ADM

CR4-5 **[5]** If the ATM functionality added to a SONET ring ADM is intended to serve as a SAM, then the ATM functionality shall meet the requirements of GR-2842-CORE.

4.1.3 Ring Side Interfaces

Ring side interfaces apply to the high-speed side of the SONET ATM VP ring ADM. These are physical layer interfaces that may carry ATM or STM signals and that interface between other like NEs, i.e., ADM, Hybrid ADM, ATM ADM, Ring DCS, and Hybrid Ring DCS. Ring side interfaces include, but not limited to:

- OC-3
- OC-12
- OC-48
- OC-192.

These ring side interfaces (OC-N signals) may use all of the bandwidth (in the case of pure ATM rings) or only a portion of the bandwidth (in the case of hybrid rings) for ATM traffic. The ATM traffic is carried in an STS-Nc within the ring side OC-N signal.

4.1.4 Drop Side Interfaces

Drop side interfaces apply to the low-speed port side of the SONET ATM VP ring ADM. These are physical layer interfaces that may carry ATM or STM signals and that interface with BSS, SAM, DSLAM, ES, CPE, Hybrid ADM, ATM ADM, and Hybrid DCS. Drop side interfaces (without SAM functions) for the different ring speeds may include, but are not limited to:

- OC-3 Ring: drop side OC-3, STS-3c, OC-1, STS-1, DS3, DS1
- OC-12 Ring: drop side OC-12 containing STS-3c, OC-3, STS-3c, OC-1, STS-1, DS3, DS1
- OC-48 Ring: drop side OC-12 containing STS-12c, OC-12 containing STS-3c, OC-3, STS-3c, OC-1, STS-1, DS3.

4.2 Functional Blocks for ATM VP Functionality in a SONET ADM

Figure 4-3 shows the ATM layer functionality from Figure 4-1 broken down into the following functional blocks:

- PHY - Physical Layer Functional Block
- VPM - Virtual Path Multiplexing Functional Block
- VPL - Virtual Path Link Functional Block
- VPCE - Virtual Path Cross-Connection Entity Functional Block.

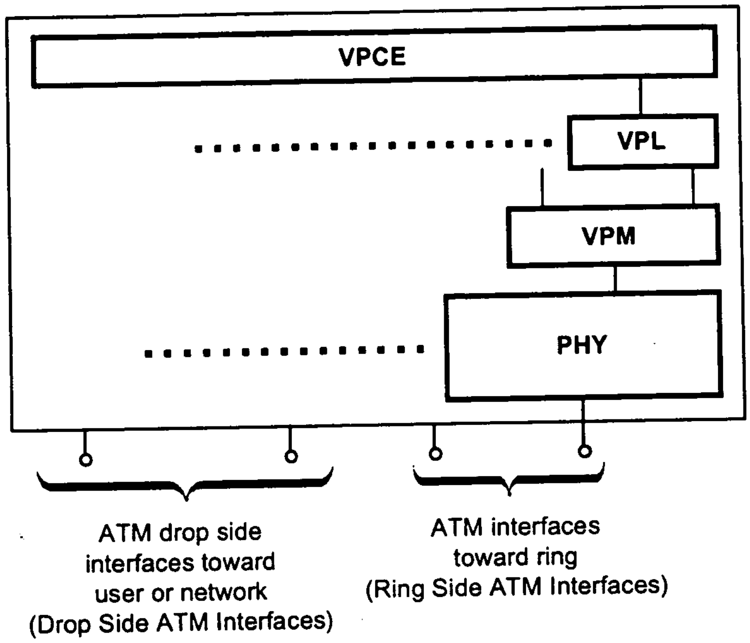


Figure 4-3. Minimum ATM VP Functionality in a SONET ADM

The functional blocks and their associated functions are the minimum amount of VP functionality that may be added to a SONET ring ADM in order for it to serve as a SONET ATM VP ring ADM. The remainder of this section focuses on identifying the functions and their requirements for each functional block.

4.2.1 PHY - Physical Layer Requirements

4.2.1.1 Drop Side Interfaces

Functions performed by the PHY functional block for the drop side interfaces include:

- transmission line coding, synchronization, and timing
- transmission overhead processing
- transmission frame generation and recovery
- transmission maintenance
- cell rate decoupling
- Header Error Control (HEC) generation and HEC check

- cell delineation
- scrambling/descrambling of ATM cell information field.

The drop side physical layer interfaces could be UNI or NNI.

R4-6 **[6]** If the drop side physical layer interface is between the user and the service provider (as in a service provider providing a user with VP service), then the physical layer interface shall meet the UNI physical layer interface requirements from the sections of TR–NWT–001112 specified.

... • Section 4 for the 155.520 Mb/s UNI

... • Section 5 for the 622.080 Mb/s UNI

... • Section 6 for the 51.840 Mb/s UNI

... • Section 7 for the 44.736 Mb/s UNI

... • Section 8 for the 1.544 Mb/s UNI.

R4-7 **[7]** For drop side non-user to service provider physical layer interfaces, the physical layer interface shall meet the NNI physical layer interface requirements from the sections of TR–NWT–001112 specified.

... • Section 9.2 for the 155.520 Mb/s NNI

... • Section 9.3 for the 622.080 Mb/s NNI

... • Section 9.4 for the 44.736 Mb/s NNI.

4.2.1.2 Ring Side Interfaces

For ring side physical interfaces, SONET section and line layer requirements should be met by the STM function. Other functions performed by the PHY functional block for the ring side interfaces include:

- STS path termination
- cell mapping
- cell rate decoupling
- HEC generation and HEC check
- cell delineation
- scrambling/descrambling of ATM cell information field.

R4-8 [8] The PHY function for the ring side interface shall terminate the SONET STS–1, STS–3c, or STS–12c path layer as described in Section 4.3.5 of TR–NWT–001112.

R4-9 [9] ATM cell streams shall be directly mapped into STS–1, STS–3c, or STS–12c SPE payload capacity of ring side interfaces, byte aligned to the SPEs, as described in GR–253–CORE.

R4-10 [10] The PHY function for the ring side interfaces shall adapt the cell rate arriving from the ATM layer to the payload capacity of the STS–1, STS–3c, or STS–12c SPEs by inserting unassigned cells when assigned cells are not available from the ATM layer.

R4-11 [11] STS–1, STS–3c and STS–12c ring side interfaces shall meet the HEC generation, HEC check, self-synchronizing scrambler, and cell delineation requirements in Section 10 of TR–NWT–001112.

4.2.1.3 Service Access Interfaces

Possible service access (drop side) interfaces for SAM functions with AAL functionality include, but are not limited to:

- ATM Cell Relay Service (CRS)
  - — for example, over DS1, DS3, STS-1, STS-3c, STS-12c
  - — VBR, CBR, UBR
- Frame Relay Service (FRS)
  - — for example, over DS1
- Native Mode LAN
  - — for example, Ethernet
- SMDS
- DS1/DS3 Circuit Emulation
- Video
- XDSL based Services.

AAL1-AAL5 may be needed to provide the service access interfaces supported.

Requirements for customer service access interfaces (physical and service adaptation functions) can be found in Section 2 of GR-2842-CORE.

4.2.2 VPM - Virtual Path Multiplexing Requirements

Functions that may be performed by the VPM (common to all VP links) include:

- VP multiplexing and demultiplexing
- VPI verification (for cells flowing toward the VPCE functional block)
- header verification (for cells flowing toward the VPCE functional block)
- Generic Flow Control (GFC) (this UNI option is not currently supported).

The VPI multiplexing and demultiplexing function enables individual cell flows to be logically combined and separated from a single flow based on VPI values.

For each cell received, the VPM must ensure that each header pattern is valid and that the VPI is not out of range or unassigned.

R4-12 [12] The VPM shall follow **R1113-32**, **33**, **34**, and **36** with respect to header and VPI verification.

4.2.3 VPL - Virtual Path Link Requirements

Functions of the VPL include:

- VPI Assignment
- VP Usage Parameter Control (UPC)/Network Parameter Control (NPC)
- Traffic Contract
- Traffic Shaping
- F4 OAM generation and processing
- F4 OAM non-intrusive monitoring
- Explicit Forward Congestion Indication (EFCI) (VPL is not required to generate EFCI, it should pass the EFCI code point through).

R4-13 [13] Ring side and non-user drop side interfaces shall use the NNI cell header format.

R4-14 [14] For NNI format interfaces, the number of allocated bits of the VPI subfield shall be in accordance with **R1113-6**.

R4-15 [15] Drop side user interfaces shall use the UNI cell header format.

R4-16 [16] For UNI format interfaces, the number of allocated bits of the VPI subfield shall be in accordance with **R1113-5**.

R4-17 [17] VPIs shall be assigned bi-directionally (with bandwidth assigned independently for each direction) for the ring side interfaces (NNI) and for the drop side interfaces (UNI or NNI). A translation shall be performed on the VPIs for each terminating VPL involved.

Note: The VPI value has no end-to-end significance over an entire VPC. An end-to-end VPC includes the VPLs within the ring. VPI translation allows for the VPI to remain the same (i.e., no new VPI assignment) for each VPL on the ring.

R4-18 [18] At connection establishment, a unique VPI for each VP link (per interface) involved in the VP connection shall be associated (VPI values may or may not be different for each VP link involved), using the following VPI allocation rules:

... • the allocated bits of the VPI subfield shall be contiguous

... • the allocated bits for the VPI subfield shall be the least significant bits of the VPI subfield, beginning at bit 5 of octet 2.

4.2.4 VPCE - Virtual Path Cross-Connection Entity Requirements

The VPCE interconnects VP links between ports by associating incoming port and VPI values with outgoing port and VPI values. The VP interconnection function shall support both UNI VPs (up to 256) and NNI VPs (up to 4096). This is a unidirectional function that includes add/drop, pass-through, and drop-and-continue at the VP level. The VPCE process may support point-to-point and point-to-multipoint VP connections.

R4-19 [19] The VPCE shall support the interconnection of VP links:

... • between any drop side ATM interfaces

... • between any ring side ATM interfaces

... • between any drop side and ring side ATM interfaces.

Note: Cell sequence integrity is maintained for all cells belonging to an entire VPC.

4.3 Other Requirements

Other common requirements include reliability and survivability of the ATM layer in the SONET ATM VP ring ADM.

4.3.1 Reliability/Availability

The overall reliability of a SONET ring (based on GR-1400-CORE or GR-1230-CORE) is not expected to be compromised as a result of adding an ATM VP layer to the ring. For example,

R4-20 [20] The downtime (i.e., unavailability) of any SONET STS–Nc path (between two particular nodes) carrying ATM traffic on a SONET ATM VP ring shall not be worse than the downtime of a SONET STS–Nc path carrying ATM traffic on an existing SONET Ring, as specified in Section 2 of GR-418-CORE.

R4-21 [21] The downtime of a two-way VP shall not be worse than the downtime of a two-way channel through an existing SONET Ring, as specified in Section 2 of GR-418-CORE.

The signal path of a two-way channel/VP is assumed to travel from an ATM interface (e.g., DS3, STS–3c) on one node to an ATM interface on another node. System availability criteria for SONET rings can be found in GR-1400-CORE and GR-1230-CORE.

4.3.2 ATM Layer Survivability

Survivability of ATM traffic is provided by ATM Protection Switching (PS) introduced in Section 2.4. Standardization efforts for ATM PS mechanisms are progressing in ITU-T SG13 and ANSI T1S1.5. ATM PS can protect the network from single link and single node failures and provide protection against ATM layer failures within the ring. It should be noted that the current standardization efforts have moved toward specifying Virtual Path Group (VPG) and VP protection as mechanisms used to protect against facility (and other physical layer) impairments, and specifying VP protection as the mechanism used to protect against ATM layer impairments (such as ATM switching matrix impairments). VC protection mechanisms, due to the potentially large number of VCs that may need to be managed, may result in large overhead and complex operations support, and thus have been relegated for further study. The main standards organizations involved with ATM PS specifications are T1S1.5 and ITU-T SG13 (Q.6), with T1S1.5 providing a central discussion point for U.S. positions going into the international standards organization.

The ATM level PS mechanism will consist of:

- Detection mechanism
- Triggering mechanism
- Coordination protocol

In addition, a holdoff mechanism for intralayer/interlayer interactions may be developed.

The first phase of ATM PS recommendation will use a dedicated resource and route allocation mechanism for point-to-point 1+1/1:1/1:n VP and VPG, on linear, mesh, and ring physical topologies. In essence, all working ATM cell streams traversing a network would have preallocated route and bandwidth for the protection entities. Having dedicated resource and route allocation simplifies the coordination and operational aspects of managing the ATM protected network. The standards organization envisioned an extension of the ATM protection switching mechanism (i.e., second phase of standardization) to provide for a semidedicated resource allocation technique, whereby the protection entity will be predetermined with zero bandwidth associated with the protection path.

As noted above, the first phase in standards will provide standards for a point-to-point ATM PS mechanism protocol. This type of PS mechanism can be used for example in a physical ring topology composed of ATM nodes via selective provisioning of user circuits providing only point-to-point ATM PS between nodes on the ring. Note that this example of using point-to-point ATM PS for a physical ring topology, is analogous to the use of point-to-point SONET protection mechanisms in existing SONET rings (e.g., UPSR).

Another implementation of ATM PS for a physical ring topology could make use of an ATM shared protection ring mechanism that has a specific coordination protocol designed to operate for a physical ring topology. This is analogous to the use of the BLSR protection protocol used for SONET today, with the difference that the ring based protection protocol would operate at the ATM layer. In the SONET world, the BLSR protection protocol is different from the point-to-point protection mechanism (e.g., squelching functions are provided in the BLSR). Standards will not initially address the use of ATM PS mechanisms that utilize an ATM shared protection ring mechanism specifically designed for ring topologies. This is for future work. It is envisioned that in this future work, an ATM shared protection ring mechanism could apply to VPG and VP, with additional functionality to cover multiple failures and interconnections with other networks.

The ATM 1+1/1:1/ VPG/VP PS will operate similar to the SONET 1+1/1:1 APS system. The VPG carries multiple VPs (or as low as a single VP) and one working VPG is protected by another dedicated VPG. The receiver at the corresponding VPG/VP termination node, based on the signal quality received, will automatically switch over to the protection VPG/VP. Messages need to be exchanged between the two end nodes of an affected VPG/VP to coordinate the switchover when failure is detected. Standard point-to-point protocols required to facilitate this message exchange are currently being addressed within T1S1.5 and ITU-T.

ITU-T recently reached the following provisional agreement on two ATM protection domain boundary types that can use existing OAM functions:

- Protection domain aligned with OAM cell flows for VPG/VP
- Protection domain uses APS channel for VPG.

The first type could support nesting of two protection domains (referred to as one level nesting, the outer level coupled with the end-to-end OAM flow and the inner level coupled

with the segment OAM flow). However, the alignment of protection domains and ATM segment OAM cell flows may introduce significant restrictions to network operators and may not be desirable. With the second type for VPG protection, the protection domain may start and end at any two nodes within the connection including end-to-end or segment OAM connections (i.e., the bridge and switch function is provided by these nodes). This is also the target for VP protection. Therefore, for the VPG/VP, multilevel nested protection domains will be allowed.

Embedding multiple protection domains for the same connection(s) is defined as nested protection. That is, these protection domains provide protection for the same network connection(s). For example, there may be the possibility of having the ATM protection domain associated with ring protection (or ring interconnection) embedded within a larger ATM protection domain such as a protection domain between two ATM switches located off of the ring (or interconnected rings).

ITU-T recently reached the following ATM coordination protocol agreement:

- One phase protocol using basics of the multiphase SONET APS protocol.

The ATM PS mechanism is only provisionally agreed to and may still change if technical flaws are identified in the provisional agreement.

The ATM protection mechanisms currently being developed within T1S1.5 and ITU-T can be applied to protect the ATM shared bandwidth on SONET ATM VP rings as noted earlier.

Two basic types of ATM ring protection switching mechanisms are envisioned:

- Dedicated point-to-point protection
- Shared protection ring mechanism.

A ring with dedicated protection utilizes the concept of 1+1 protection applied to a physical ring topology to provide protection of ATM traffic. A shared protection ring utilizes the concept of 1:n protection applied to a physical ring topology to provide protection of ATM traffic.

A dedicated protection ring transports working traffic on both the working and protection entity during failure-free and failure events, thus allowing traffic recovery to be accomplished by a simple switch at the sink node from receiving the working entity traffic to receiving the protection entity traffic. A unidirectional protection switch for the 1+1 protection would only involve the switch at the sink node. The ATM PS mechanism for 1+1 unidirectional protection mode does not require a coordination protocol. For a bi-directional 1+1 protection switching mechanism, a point-to-point coordination protocol may be needed between the source and sink nodes.

R4-22 **[22] A hybrid VP UPSR or ATM UVPSR shall use the ATM 1+1 VPG/VP PS point-to-point mechanism being developed within standards.**

An ATM protection mechanism for the ATM shared bandwidth on a SONET UPSR will be necessary to prevent ring exhaustion and to provide protection of node failures for pass-through ATM traffic.

A shared protection ring transports working traffic on the working entity during failure-free conditions and bridges the working traffic to the protection entity during a failure event. Shared protection ring architectures are similar to point-to-point 1:n protection architectures; the difference stems from the method of sharing the protection entity among working entities. This will require a specific shared protection ring coordination protocol to be developed. In a shared protection ring architecture, the protection entity may be used to protect any working entity around the ring that requires the protection capability. A hybrid VP BLSR or ATM BVPSR may make use of a future ATM 1:n VPG/VP PS shared protection ring coordination protocol.

The deployment of ATM protection mechanisms on SONET BLSRs (i.e., hybrid VP BLSR) will be dependent on the development of an effective ATM squelching mechanism.

4.3.2.1 1+1/1:1 VPG/VP Protection

Fundamental requirements for an ATM dedicated protection ring PS mechanism can be found in GR-2980-CORE. The requirements in GR-2980-CORE provide for point-to-point or linear 1+1/1:1 protection. The goal with GR-2980-CORE is to align with agreements from standards.

4.3.2.2 1:n VPG/VP Protection

A 1:n ATM PS mechanism provides protection of n working entities using one protection entity. In a 1:n protection mode, only one working entity may be protected by the protection entity. Future issues of GR-2980-CORE will include requirements for point-to-point 1:n protection.

Additional requirements for shared protection ring configurations (i.e., specification of an ATM PS shared protection ring coordination protocol) to allow sharing of the protection entity around the ring and to cover multiple failures and interconnection may be necessary and are for further study. Operational aspects and interconnection with other systems are different for ring configurations than point-to-point or linear applications.

4.3.2.3 Protection Performance

The goal in standards for the ATM point-to-point PS mechanism currently being developed is to provide protection switching times as fast as possible. The exact switching times (e.g.,

50 ms, 100 ms, 150 ms) are not known yet and are for further study. Ring protocols may also provide different switching times.

4.3.3 SONET and ATM Layer Protection Interaction

The interworking of different survivability mechanisms within the same portion of the same network (e.g., ring), or the interworking of different survivable networks (or network segments) is called escalation. For SONET ATM VP rings, the ATM shared bandwidth could be protected by both SONET layer mechanisms and ATM layer mechanisms (BLSR only) or solely by SONET or ATM layer mechanisms (where the SONET layer is still used as a transport medium on the ring). If the ATM shared bandwidth is protected by both SONET and ATM layer mechanisms, when network failures occur, coordination between these different restoration mechanisms within the ring is needed such that any affected ATM traffic that cannot be restored by the SONET layer can be handed over to the higher ATM layer, e.g., from 1+1 SONET APS to 1+1 ATM APS. Another example would be to use the SONET layer for span switching and the ATM layer for ring switching on a 4-fiber BLSR. Otherwise, a poorly planned escalation strategy could result in various survivability mechanisms contending with each other for spare facilities, slower restoration times, or even the inability of the ring to recover from certain failures. To avoid having the restoration mechanism at both SONET and ATM layers invoked concurrently, certain delay (generic holdoff) needs to be inserted between these two layers before the higher ATM layer restoration mechanism is activated.

The topic of a generic, provisionable holdoff function in ATM survivability escalation is a current issue in standards. The higher layer holdoff could be implemented at the endpoint of the higher layer protected path, or at the node where the higher layer is notified of upstream failures that could cause the initiation of higher layer protection switching. For instance, the holdoff could be implemented to prevent the next layer, e.g., ATM layer, from attempting to restore traffic (by delaying insertion of VP-AIS for ATM protection switching purposes) that could be restored by the SONET protection mechanism. This delay could be made to allow operation of the next layer as soon as possible or be delayed, e.g., up to 100 ms (values are for further study). There is also discussion in standards to allow the lower layer (e.g., SONET) to provide protection switching. If this layer cannot protect against the failure, an interlayer messaging function will send information to other higher layers, i.e., ATM, to allow those layers to attempt the protection.

4.3.4 Ring Interconnection at the ATM Layer

Ring interconnection, introduced in Section 2.5, assuming dual-node ring interconnection or dual homing for ATM, involves the issues of drop-and-continue of ATM signals (at the VP level) and interworking with existing conventional SONET rings.

Both the SONET UPSR and BLSR utilize an STM level 1+1 protection scheme when providing dual-node ring interconnection, according to GR-1400-CORE and GR-1230-CORE respectively. Therefore, when STM layer protection mechanisms are used for ring interconnection, requirements given in GR-1400-CORE and GR-1230-CORE should apply. To assure interworking between SONET ATM VP Rings and conventional SONET Rings, the ATM interconnection protection scheme should utilize a 1+1 protection scheme as well.

Using a 1+1 protection scheme requires the ability to duplicate the interring circuit as well as provide a selector function to select the better of the two interring circuits at the destination. Duplication of the circuit is provided via the drop-and-continue function. The drop-and-continue function and/or the selector function can be performed at the SONET or ATM layer for ring interconnection. Bellcore analysis indicates that significant benefits with respect to bandwidth efficiency and VP management are realized when providing these functions at the ATM layer for all types of SONET ATM VP Rings.

For an example of dual-node ring interconnection using these functions at the ATM (VP) layer for an ATM UVPSR, see Figure 3-9. Note these same ATM VP layer functions would be used for a Hybrid VP UPSR. In Figure 3-9, the ring interconnections are provided at two diversely located nodes, with two different drops and two different feeds between rings. The selector function is provided on the egress direction of traffic on the first ring. The selector function selects the better of the two copies of the interring circuit and drops the selected signal to the second ring. A further selector function at the destination node on the second ring (not shown in Figure 3-9) selects the better of the two copies from the two different ring directions. For a Hybrid VP BLSR or ATM BVPSR, the selector function would be on the ingress direction of traffic to select between duplicate interring circuits, each carried over a different interconnection link.

R4-23 **[23]** For ring interconnection at the ATM layer, the drop-and-continue function shall be provided at the ATM layer.

The drop-and-continue function is needed to support dual homing ring interconnection for ATM. Dual homing requires the two interconnecting ADMs on the same ring to coordinate VP drop-and-continue. Another ATM ring interconnection method may be possible such as "dual transmit." This method utilizes the "dual transmit" at the source node on the ring to provide dual node ring interconnection capability. Other ATM ring interconnection methods may also be utilized and are for further study.

R4-24 **[24]** For ring interconnection at the ATM layer, the selector function shall be provided at the ATM layer.

It is likely that this ATM protection domain associated with ring interconnection will be embedded within other ATM protection domains. Thus, the ATM protection scheme used to protect interring circuits would have to support nested protection. Nested protection is described in Section 4.3.2.

5. Common ATM Operations Functionality and Criteria

This section reviews ATM operations functionality and presents criteria for SONET ATM VP ADMs. It covers the operations architecture, operations functions and how they are supported by operations communications, operations flows between transport end points, and operations interfaces.

The introduction of ATM operations functionality into the SONET ring ADM should not impact the STM operations functionality of the SONET "layer" of the Hybrid ring or pure ATM ring.

R5-1 [25] All operations requirements for the SONET layer found in GR-1400-CORE, GR-1230-CORE, and GR-253-CORE must be followed for Hybrid ADMs, where applicable.

5.1 TMN Operations Architecture

The Telecommunications Management Network (TMN) architecture is based on a multi-layered model of operations as defined in ITU-T Rec. M.3010 and further addressed in TA-TSV-001294, GR-2869-CORE, and ANSI T1.210. TMN supports the management requirements of administrations to plan, provision, install, maintain, operate and administer telecommunications networks and services. A TMN provides management functions for telecommunications networks and services and offers communications between itself and the telecommunications networks, services, and other TMNs.

The TMN model provides the management context for the SONET ATM VP ADMs. TMN is a logical management model, providing a functional decomposition of management functions into logical management layers and management functional areas. TMN is also an architectural model, espousing open/standard interfaces among management applications (e.g., OSs) as well as between management applications and the network resources being managed (e.g., NEs). As shown in Figure 5-1, the TMN logical management layers are: the Network Element Layer (NEL), Element Management Layer (EML), Network Management Layer (NML), Service Management Layer (SML), and Business Management Layer (BML). These are logical management layers that provide a logical and consistent separation of management functions with well-defined interfaces, without implying any specific physical implementation. Physical implementations may choose to integrate two or more of these layers. These layers can be briefly summarized as

- **BML**: Goal setting, finance, budgeting, and planning
- **SML**: Contacts with customer, identification of customer access to network, billing maintenance and reporting quality of service data
- **NML**: Control coordination of the whole network, nodes and links, provisioning and maintenance of network capability, and statistics and history pertaining to circuits

- **EML**: Control and coordination of a subset of NEs, gateway to NEs for NML and higher layers, maintenance of statistics and history of individual NEs
- **NEL**: Telecommunication activities of the resource components of NEs, implementation of management commands, detection of problems, and autonomous activities.

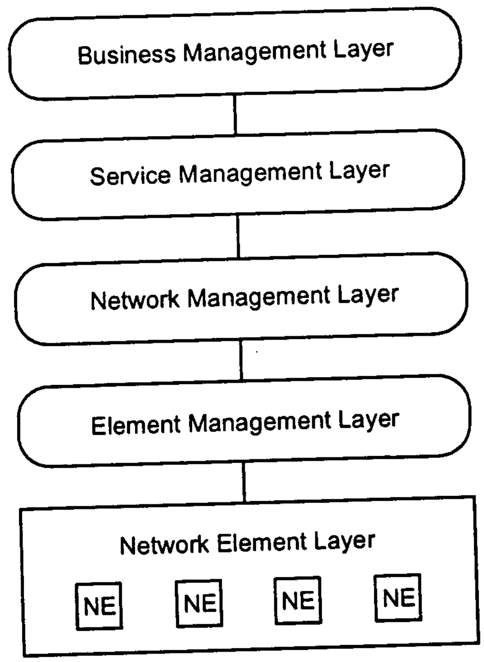


Figure 5-1. Multi-Tiered Operations Architecture, TMN Model

The NEL and portions of its EML are covered in the following subsections.

The TMN concept also introduces five Management Functional Areas (MFAs): Configuration Management, Fault Management, Performance Management, Accounting Management, and Security Management as depicted in Figure 5-2. The following summarizes these five MFAs.

- **Configuration Management** exercises control over, identifies, collects data from, and provides data to NEs and the connections between NEs. Configuration Management is responsible for the planning/installation of NEs, their interconnection into a network, and the establishment of customer services that use that network.
- **Fault Management** enables the detection, isolation, and correction of abnormal operation of the telecommunications network and its environment.

- **Performance Management** evaluates and reports upon the behavior of telecommunications equipment and the effectiveness of the network and NEs for the support of services.
- **Accounting Management** enables the use of the network services to be measured and the costs for such use to be determined. It provides facilities to collect accounting records and to set billing parameters for the usage of services and for periodic charges for access to the network.
- **Security Management** provides for prevention and detection of improper use of network resources and services, for the containment of and recovery from theft of services or other breaches of security, and for security administration.

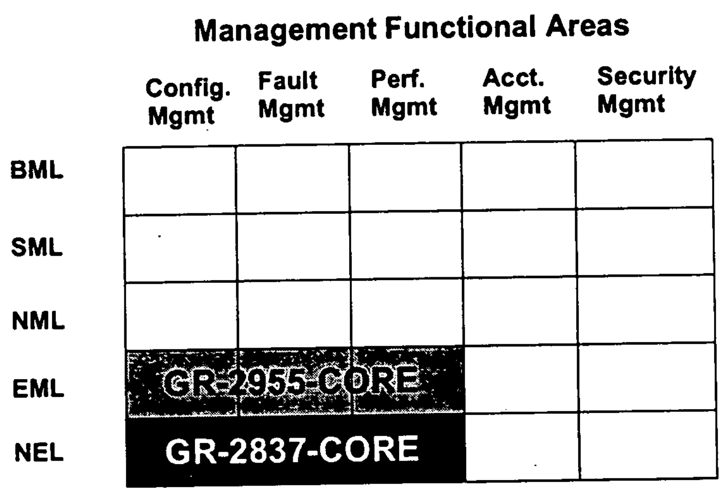


Figure 5-2. TMN Layers and Management Functional Areas

The TMN information architecture of ITU-T Rec. M.3010 describes an object-oriented approach for information exchanges in interactive management transactions, i.e., those that implement the Common Management Information Service Element (CMISE)[1]. The TMN information models are defined in ITU-T Recommendations, such as ITU-T Rec. M.3100 and G.774.

The management approach for ATM networks and BSSs is based on the TMN concept and requirements for EML and NEL on ATM NEs are given in GR–1248–CORE. The SONET operations approach is also consistent with the TMN concept, as described in GR–253–CORE, Section 8.

1. The CMISE Application Service Element (ASE) in a system (e.g., an NE) employs the Common Management Information Protocol (CMIP) across the interface to other systems (e.g., other NEs or OSs).

5.1.1 Operations Architecture Evolution

Three basic types of operations architectures are distinguished on the basis of management scope for different NE technologies. The NE technology categories include: SONET NE, ATM NE, and Hybrid NE. Each operations architecture type is defined on the basis of its management scope with respect to NE type as shown in Figure 5-3:

- Technology-specific operations architecture
- Hybrid operations architecture
- Integrated operations architecture.

In the current (unintegrated) network management environment, SONET NEs are managed by a SONET-specific EMS and sub-NMS, and ATM NEs are managed by an ATM-specific EMS and sub-NMS, as shown in Figure 5-3a. Management integration is assumed to take place at an NMS. The introduction of a hybrid NE with combined SONET/ATM functionality into this environment could potentially be handled via separate interfaces to the SONET EMS and ATM EMS, as shown in Figure 5-3b. However, disjoint management of an integrated element such as a hybrid has a number of drawbacks. A general implication is that careful coordination is required between the two EMSs to ensure unambiguous management actions, particularly in the management of shared resources such as common equipment modules. This scenario is not considered a likely alternative for deployment.

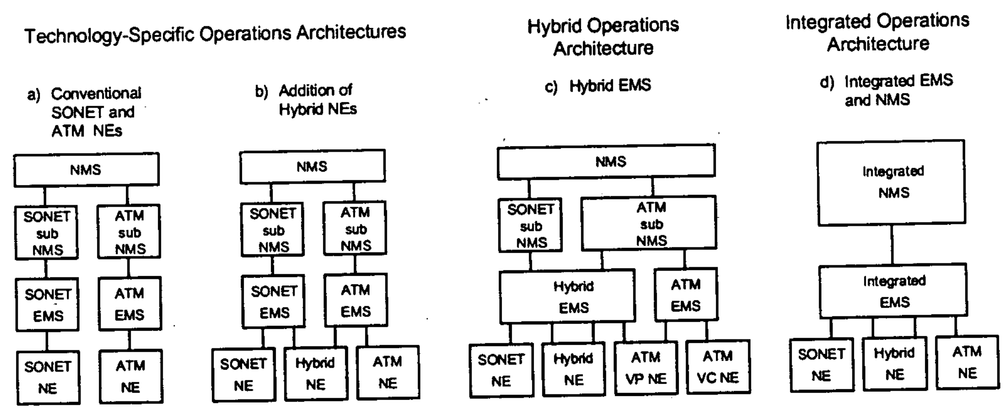


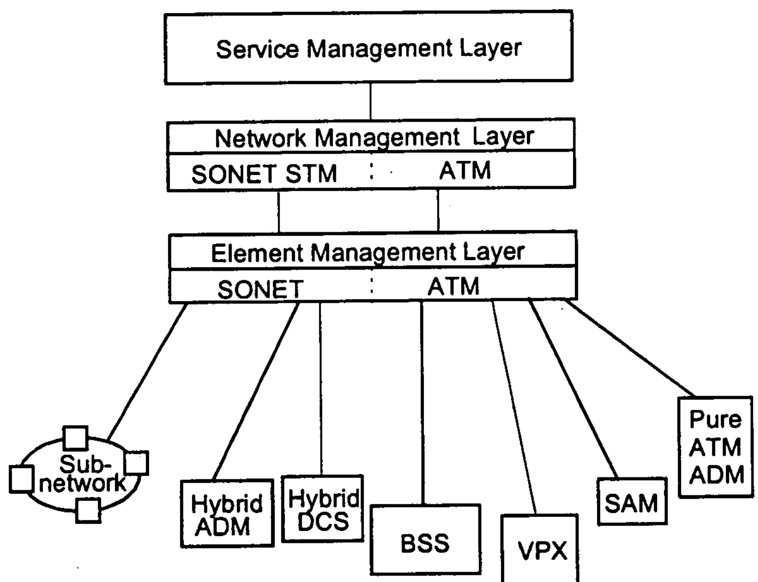
Figure 5-3. Operations Architecture Evolution

The introduction of a hybrid EMS, with management responsibility for SONET NEs and hybrid NEs, as shown in Figure 5-3c, is a more likely scenario. This likelihood is especially true if the hybrid is an extension of a SONET supplier's NE product providing basic ATM functions such as VP cross-connection. An ATM EMS is assumed to manage the (pure) ATM NEs with VC functionality in such a network. (A SONET EMS could potentially coexist in a network with a hybrid EMS.) Generic requirements for a hybrid SONET/ATM EMS are given in GR-2955-CORE.

Further management coordination could be attained with an integrated operations architecture in which integrated EMSs have management responsibility for SONET NEs, hybrid NEs, and ATM NEs (Figure 5-3d).

5.1.2 Hybrid Operations Architecture

A hybrid network element such as a Hybrid ADM, has two types of operations information, one related to the SONET layer and one to the ATM layer. Consequently, the associated OS functions must cover SONET STM Network Management as well as ATM Network Management, and these functions may be reported to a Service Management layer according to the TMN model. Figure 5-4 shows the management layers that support the different functions of the hybrid NE and some of the NE types that the management layers may serve.



Subnetwork	Collection of SONET ADMs
Hybrid ADM	SONET ADD/Drop Multiplex with ATM VP Functionality
Hybrid DCS	SONET DCS with ATM VP Functionality
BSS	Broadband Switching System
SAM	ATM Service Access Multiplexer
VPX	VP Cross-Connect

Figure 5-4. TMN Architecture - Hybrid Operations

For the Hybrid ADM, the operations interface would ideally consist of a single interface connecting to the EML rather than separate interfaces for the two types of operations information (i.e., SONET and ATM). Initially, element management support for Hybrid

ADMs may be performed by two separate Element Managers, one for the SONET functions and one for the ATM functions. The hybrid NE will generate alarms and performance information for both the SONET layer and the ATM layer. Some of this information will pertain to both layers of the NE. In this case, the information will need to be correlated and it must be determined which information should be passed up to the network and service management layers for action to be taken. Using OSI/CMISE for both types of operations information should help facilitate implementation of a single management interface.

For Hybrid ADMs, two layers of operations functions can be distinguished, at the SONET physical layer and at the ATM logical layer. SONET-based operations or management functions remain largely unchanged. For the SONET layer, general requirements for maintenance (alarm surveillance, performance monitoring, and testing) and memory administration are given in GR–253–CORE, Section 6. For the ATM layer, general requirements that apply to the Hybrid ADM can be found in GR–1248–CORE. Not all ATM requirements apply to the Hybrid ADM. Preliminary operations requirements specific to the Hybrid ADM are provided in this section.

5.2 Operations Functions

Network operations encompass the set of operations functions directly concerned with the day-to-day functioning of the networks of a network provider. These functions support operations personnel in

- Configuring the network to provide service (Configuration Management)
- Detecting, localizing and correcting network faults and troubles (Fault Management)
- Ensuring that the overall network performance and service level objectives are met (Performance Management).

OSs are largely responsible for provisioning, maintaining, and administering the network. Operations features for NEs are also required to support network operations. OSs communicate with NEs mostly via generic operations interfaces, commonly referred to as OS/NE interfaces. Various operations functional areas may be handled by different OSs, each one handling a certain set of functions. For broadband networks, such operations functions include maintenance, memory administration, network traffic management, network data collection, and Customer Network Management (CNM).

5.2.1 Configuration Management

Configuration management provides functions for OS database support including updates, backups, restorals, and data integrity. The following subsections describe the configuration management functional areas for the SONET ATM VP Ring node. Provisioning ATM

routing information (VPI values) to either establish (or release) a VP link on the SONET ATM VP ADM falls in the area of configuration management. The administration of VPIs through the SONET ATM VP ADM introduces a new function for the management system compared to pure SONET ADMs. A VPI routing table will be required for each SONET ATM VP ADM as part of the configuration of VP services at the NE to support the VPI assignment information, such as VPI values, input and output ports, and potentially traffic descriptors and QoS class information.

5.2.1.1 External Update Support

The SONET ATM VP ADM will need to identify itself and report changes in its configuration.

R5-2 [26] The SONET ATM VP ADM shall meet the requirements specified in Section 5.1 of GR–1248–CORE for external update support.

5.2.1.2 Memory Update Support

The SONET ATM VP ADM will need to update its database in response to operations requests by network management systems. This includes information for configuring interfaces, VPLs, VPCs, point-to-point ATM VP cross-connections, VPC OAM segment end points, ATM NE functions, and suppressing/duplicating autonomous messages.

R5-3 [27] The SONET ATM VP ADM shall be able to configure drop side interfaces as a Broadband Intra-Network Node Interface (B-INNI) and maintain B-INNI interface parameters as specified in **R1248-27** in GR–1248–CORE.

Regarding R5-3, not every item listed in **R1248-27** may be required to be supported because the SONET ATM VP ADM may not set-up VPCs and VCCs.

CR5-4 [28] If a UNI is supported, the SONET ATM VP ADM shall be able to configure drop side interfaces as a UNI and maintain UNI interface parameters as specified in **R1248-27** in GR–1248–CORE.

R5-5 [29] The SONET ATM VP ADM shall maintain information in accordance with **R1248-28** for each VPL it terminates.

Regarding R5-5, the traffic and QoS descriptors that are maintained (e.g., ingress and egress peak cell rate and sustainable cell rate) for each VPL, can be used to support a policing function.

R5-6 [30] The SONET ATM VP ADM shall be able to configure point-to-point and multipoint ATM VP cross-connections as specified in **R1248-32, 33, 34, 35, 36, 37, 38, 39** in GR–1248–CORE.

Regarding R5-6, note that only multicast (point-to-multipoint) is currently feasible. However, the SONET ATM VP ADM should be designed to support management of merge functionality as it becomes defined. A type of multicasting connection application is described in Section 3.3.2.

The concept of segment end points for administering segment operations flows exists in ATM nodes. Segments are a concatenation of one or more VP or VC links. Segment end points are specified by the network management system issuing commands to the ATM NE. The ring node needs to support management system requests to set up segment end points. Segment operations flows use OAM cells to communicate operations information within one or more concatenated VP/VC links.

R5-7 [31] The SONET ATM VP ADM shall be able to identify a VPL termination point as a VPC OAM segment end point as specified in **R1248-40** and **41** in GR–1248–CORE.

R5-8 [32] The SONET ATM VP ADM shall be able to activate/deactivate ATM NE functions as specified in **R1248-42** in GR–1248–CORE.

R5-9 [33] The SONET ATM VP ADM shall provide message suppression/duplication capabilities as specified in **R1248-43** and **44** in GR–1248–CORE.

5.2.1.3 Memory Query Support

In addition to performing updates, the SONET ATM VP ADM will need to support database queries.

R5-10 [34] The SONET ATM VP ADM shall provide memory query functions as specified in **R1248-45** in GR–1248–CORE.

5.2.1.4 Memory Backup and Restoration

In addition to performing updates, the SONET ATM VP ADM will need to support database backup and restoration.

R5-11 [35] The SONET ATM VP ADM shall provide memory backup and restoration features as specified in **R1248-46** and **50** in GR–1248–CORE, except that memory backup may be stored external to the NE.

Other memory backup and restoration requirements in GR-1248-CORE are for further study.

5.2.1.5 Software Download Support

In addition to performing updates, the SONET ATM VP ADM will need to support software download.

R5-12 [36] The SONET ATM VP ADM (or adjunct) shall meet the software download requirement as specified by **R1248-54** in GR-1248-CORE.

Remote software download requirements in GR-1248-CORE, i.e., **O1248-55**, are for further study.

5.2.2 Fault Management

Fault management criteria are used to detect, verify, and isolate troubles to maintain the SONET ATM VP ADM (including its components), its physical facilities, and its logical connections. There are two general fault management categories:

- alarm surveillance functions, which include fault monitoring and fault notification capabilities
- fault localization and testing functions, which include capabilities that enable a Management System to sectionalize a fault, analyze circuit and equipment characteristics, and enable the SONET ATM VP ADM to diagnose its own internal status.

5.2.2.1 Alarm Surveillance

In the area of fault management, NE alarm surveillance is unchanged from existing requirements.

R5-13 [37] The SONET ATM VP ADM shall meet the generic maintenance requirements for trouble detection for NEs as well as ATM NEs as specified by **R1248-56** in GR-1248-CORE.

The necessary ATM OAM functions for the ring need to be supported, such as VP link failure indications (VP-AIS, VP-Remote Defect Indication [RDI]) via OAM cells. For example, when SONET trouble affects the ATM layer, VP-AIS OAM cells need to be sent downstream to be detected and alarmed by the ATM NE at the VPC end point. This tells the ATM NE of physical trouble on the VPC and the SONET alarms (or OAM cell loopback) will help locate the cause. Note that the SONET (physical) STM layer will alarm

first before alarms are passed to the ATM layer. See Figure 6-7 in GR–1248–CORE for an illustration of SONET/ATM maintenance signal interaction at the ATM interface.

R5-14 **[38]** The SONET ATM VP ADM shall meet the ATM VP layer defect detection requirements as specified in **R1248-63, 64,** and **70** in GR–1248–CORE.

Note that **R1248-64** does not address ATM Protection Switching (however, it does not preclude it) - see Section 4.3.2.3.

Standard failure timing and fault notification would need to be supported. In addition, new alarms (special messages) may be needed (e.g., for an ATM processor failure within a ring node).

R5-15 **[39]** The SONET ATM VP ADM shall meet the failure timing and failure notification requirements as specified in **R1248-72, 73, 74, 75,** and **76** in GR–1248–CORE.

Regarding **R5-15**, this applies to failures detected locally, both SONET and VP level defects and failures. Failure notification inferred from defect indications is for further study, specifically, **R1248-77** and **78** in GR–1248–CORE.

Fault management also covers the ATM transmission interfaces to the ring node (e.g., DS3 and OC–N), including the link between the ring node and the BSS, which are subject to standard physical layer defects and failure detection. Alarm surveillance (e.g., loss of signal, loss of frame, Loss of Cell Delineation [LCD]) for ATM over DSn and ATM over SONET is unchanged.

R5-16 **[40]** The SONET ATM VP ADM shall meet the requirements for physical layer defect and failure detection as specified in **R1248-57, 58, 59, 60,** and **62** in GR–1248–CORE.

5.2.2.2 Fault Localization and Testing

Fault localization and testing functions are used to isolate internal SONET ATM VP ADM functionality NE failures down to the smallest repairable/replaceable unit of hardware/software, as well as to enable the network provider to perform tests on individual VPCs. Generic maintenance requirements for SONET ATM VP Ring Nodes include the need for testing functions and internal diagnostics.

O5-17 **[41]** The SONET ATM VP ADM should meet generic maintenance requirements for trouble isolation and provide internal supplier-specific diagnostics as specified by requirements **R1248-79, 80, 81, 82,** and **O1248-83** in GR–1248–CORE.

For fault localization and testing, OAM cell loopback and OAM Continuity Check (CC) capability may be needed. The main points of the loopback and the CC mechanism are to find ATM specific troubles and to verify an active connection, respectively. Both capabilities would be used on a VPC basis as well as a segment basis. The CC mechanism and RDI OAM can identify ATM/latent troubles on the connection. The BSS could originate the OAM cell loopback function to locate ATM troubles that may be caused by the ring. A loopback failure would indicate that no loopback is received.

CR5-18 [42] The SONET ATM VP ADM may be required to provide OAM cell loopback capability support on VP (F4) Flows at segment end points as specified in **R1248-87, 89,** and **92** in GR–1248–CORE.

Regarding **CR5-18**, only support for looping back received loopback cells is provided. It is assumed that origination of loopback is done by the BSS. Providing loopback capability support at intermediate points is for further study.

CR5-19 [43] The SONET ATM VP ADM may be required to provide the CC capability on VPCs and segments as specified in Section 6.1.2.4 in GR–1248–CORE.

For Hybrid ADMs, SONET section and line overhead terminate at all ring nodes (assuming no regenerators). The two available layers of SONET alarms (along with PM) should detect and fault locate essentially all SONET (physical) trouble on spans between ring nodes and on SONET access links between ring nodes and BSSs. The SONET STS-N(c) path terminates between nodes having ATM access. This additional path layer of SONET alarms (along with PM) is also available for trouble isolation on the equipment.

5.2.3 Performance Management

Performance management includes gathering and analyzing statistical data for both performance monitoring (for network maintenance) and for Network Traffic Management purposes. PM of the physical facilities and of the ATM VP/VC connections, protocol monitoring of OAM cells at the ATM layer, and traffic management (if congestable ATM modules are used) are supported capabilities.

5.2.3.1 Monitoring of Physical Transport Facilities

Facility monitoring requirements must be met for ATM over DSn and ATM over SONET regarding drop side interfaces to the ring.

R5-20 [44] The SONET ATM VP ADM shall meet the PM requirements specified in Section 7.1.1.1 of GR–1248–CORE for the appropriate DSn ATM drop side interfaces to the ring.

Facility monitoring requirements for ATM over SONET are unchanged from as described in GR-253-CORE for an ATM mapped SONET signal.

5.2.3.2 Protocol Monitoring/Analysis

Protocol monitoring of the ATM cell header processing is required on a per interface type basis (e.g., UNI). Counts are made on cells discarded due to HEC violations, ATM header errors, and out-of-cell delineation anomalies. For the SONET ATM VP ADM, this will be done for the ATM cell header processing functions associated with each direction of transmission on the ring.

R5-21 [45] The SONET ATM VP ADM shall meet the requirements for monitoring the ATM cell header processing as specified in **R1248-97, 98,** and **99** in GR-1248-CORE.

Requirements **R1248-100, 101,** and **O1248-102,** in GR-1248-CORE, for logging cell abnormality due to unrecognized VPI/VCI values. Cell header abnormality logging is for further study.

Protocol monitoring on OAM cells to monitor for errors in the processing of OAM cells (e.g., counting number of OAM cells with invalid OAM fields) is a desirable feature. This includes counting and thresholding on a per OAM processor basis in support of VP service operation.

O5-22 [46] It is an objective for the SONET ATM VP ADM to meet the objective in GR-1248-CORE, **O1248-102,** for protocol monitoring of OAM cells.

AAL protocol monitoring is not required since ATM connections are not terminated at SONET ATM VP ADMs (without SAM functions). Performance management of an AAL is conditional on whether the AAL is supported. It is expected that AAL processing will occur at non-UNI service access interfaces.

5.2.3.3 ATM VP Performance Monitoring

Performance management at the ATM layer is supported using OAM PM cell flows as developed in GR-1248-CORE, Sections 4, 7, and 8. VP/VC PM functions have been defined and include the PM cell generation, PM data collection, and activation/deactivation cells for PM. Information in PM (OAM) cells can be used to determine cell loss, cell misinsertion, or cell delay on a given VPC or VP segment.

The need for SONET ATM VP ADMs to support OAM PM cell flows on VP segments between them depends heavily on the network architecture. If there is no VP cross-connecting and/or ATM layer multiplexing occurring at the intermediate network elements between the SONET ATM VP ADMs, then the ATM NEs (e.g., VPX, BSS) to which the

VPs are added/dropped can assume responsibility for the OAM PM cell flows. However, when multiple ATM layer multiplexing and/or cross-connects take place on the VP segments between the SONET ATM VP ADMs, then VP OAM PM cell flows need to be supported to facilitate trouble isolation at the ATM layer.

CR5-23 [47] If a SONET ATM VP ADM needs to support point-to-point VP OAM PM cell flows, then the requirements in GR-1248-CORE Sections 4.2, 7.1.3, and 8 shall apply addressing OAM PM cell formatting, generation, and activation/deactivation that are needed to monitor the following performance parameters:

... • number of 0+1 user cells lost (i.e., background cell lost)

... • number of 0 cells lost (i.e., cells lost between the source ATM NE and the destination ATM NE)

... • total number of misinserted cells (i.e., cells misrouted to the destination ATM NE)

... • errored cell events (i.e., cells delivered to the destination ATM NE with bit error(s) in the payload).

Regarding CR5-23, it is applicable to VP segments, not end-to-end VPCs.

5.2.4 Security Management

No new issues have been identified as a result of putting ATM VP functionality in SONET rings. Security Management Requirements can be found in Section 6.1.6 of GR-253-CORE, Section 11 of GR-1248-CORE, and GR-815-CORE, and vary depending on whether the ATM NE is accessible via public means (e.g., dial up). Access via public means is not anticipated for the SONET ATM VP ADM and should be the same access as any ADM.

5.2.5 Accounting Management

Accounting management requirements for any drop side UNI interfaces are currently under investigation.

Usage sensitive billing functions are not relevant to SONET ATM VP ADMs with capabilities limited to VP cross-connection.

5.3 Network Traffic Management

5.3.1 Functions and Procedures for Traffic Management

5.3.1.1 Introduction

ATM traffic on a SONET/ATM network can be generated by a wide variety of services and applications. Whether this widely diverse traffic (in terms of characteristics and service quality requirement) can be orderly managed and whether the anticipated statistical multiplexing gain can be achieved (resulting from multiplexing multiple ATM cell streams onto the same STS-Nc path while still providing appropriately differentiated Quality of Service [QoS]) is technically challenging. The economic benefits of the SONET ATM VP ring are fundamentally related to the ability of each SONET ATM VP ring node to successfully protect the network from congestion and to efficiently utilize the network bandwidth.

To meet the above objectives, a framework of three traffic management functions are specified as requirements. These requirements (described in Section 5.3.4) focus on the PVC and VP implementations in a UPSR or BLSR environment. The functions are:

- Connection Admission Control (CAC)- this is the set of actions performed by each SONET ATM VP ring node during the connection set-up phase in order to determine if there are sufficient network resources and bandwidth to support the request (these functions are discussed in more detail in Section 5.3.1.2).
- Policing- this is the set of actions taken by each SONET ATM VP ring node to monitor and control traffic at a SONET/ATM network access point (e.g., SAM interface, native LAN interfaces, etc.). The main function is to verify that the incoming (new add-on) traffic is in compliance with the negotiated traffic rate at connection establishment. Policing may (optionally) also include the action of traffic shaping that alters the traffic characteristics of a stream of cells on a connection to ensure conformance at a subsequent SONET ATM VP ring node interface (these functions are discussed in more detail in Section 5.3.1.3).
- Selective Cell Discard- this is the selective action taken by each SONET ATM VP ring node to discard non-compliant ATM cells (this function is discussed in more detail in Section 5.3.1.4).
- Explicit Forward Congestion Indication (EFCI)- although not a requirement, this function provides traffic congestion indications: 1) to downstream NEs that can initiate congestion reduction actions and 2) to facilitate the selection of least delay STS-Nc path for ATM cell transport. This function is addressed in a future issue of this GR.

The ATM service categories covered by the traffic management requirements are:

- CBR- Constant Bit Rate. This service category is used by connections that request a static amount of bandwidth that is continuously available during the connection lifetime. This amount of bandwidth is characterized by a Peak Cell Rate (PCR) value.
- VBR- this includes real-time Variable Bit Rate and non-real-time Variable Bit Rate. The real-time VBR is intended for real-time applications (i.e., voice and video applications) where the sources are expected to transmit at a rate that varies with time (described as "bursty" sources). Non-real-time VBR service category is for bursty sources that have no associated delay bounds. VBR bandwidth demand is characterized by PCR, Sustainable Cell Rate (SCR), and Maximum Burst Size (MBS).
- UBR- Unspecified Bit Rate. This service category is intended for non-real-time applications (e.g., email and Internet file transfer) that have no specified traffic related service guarantees.

The specification of traffic management requirements for ABR (Available Bit Rate) traffic is for further study. The definitions of above service classes (where each ATM VP connection has VCs belonging to the same class) conform to those defined in the ATM Forum Technical Committee's Traffic Management Specification Version 4.0. Traffic management functions such as CAC and Selective Cell Discard are, in general, structured differently for each service category. The above service categories relate traffic characteristics and Quality of Service (QoS) commitments (e.g., maximum Cell Transfer Delay [CTD], peak-to-peak Cell Delay Variation [CDV], and Cell Loss Ratio [CLR]) to network behavior. These QoS parameters are discussed in more detail in Section 5.3.3.

It should be recognized that the traffic management requirements (specified in Section 5.3.4) for the SONET ATM VP ring nodes are to ensure that the anticipated economic benefits of adding ATM traffic to SONET rings can garner the maximum transport efficiency even under heavy traffic load. The architecturing of these requirements is based on the distributed processing paradigm where each SONET ATM VP ring node executes its own traffic management functionalities (no additional interfacing requirements for BSS (GR-1110-CORE) and SAM (GR-2842-CORE)). The point emphasized here is that the performance requirements stated in this section are minimal enhancements (the set of three traffic management functions specified is the minimal set out of the full set of ATM traffic management functionalities specified in GR-1110-CORE and the ATM Forum's Traffic Management Specification Version 4.0) needed to attain the benefits of ATM multiplexing in SONET rings.

5.3.1.2 Connection Admission Control

In a SONET/ATM network, multiple ATM connections can share a single STS-Nc path on a statistical basis (where each path supports a mix of connections with various ATM service categories). Because of the bursty nature of ATM VBR traffic, it is not obvious whether the idle capacity of an ATM path (a STS-Nc) is sufficient for an incoming (new add-on) connection or not. If a connection is accepted, the QoS of all existing connections on the

path, as defined by CLR and CTD, may be influenced by the new connection. Therefore, in any SONET ATM VP ring node a decision rule for acceptance of new connections is required. This decision rule is called a CAC algorithm.

CAC algorithms (not standardized by the ATM Forum Technical Committee on Traffic Management) can have various degrees of complexity. The simplest CAC reserves the amount of bandwidth equal to the PCR for each connection. An incoming connection is accepted only if the sum of the PCRs of the existing connections and the new connection do not exceed a predefined critical value (bandwidth utilization threshold) that guarantees that the QoS requirements are met. This algorithm, while effective in managing CBR traffic, has the disadvantage that the capacity of the ATM path is not effectively used when the traffic is bursty (i.e., VBR traffic). However, if the PCR is not reserved for every connection, a momentary bandwidth overload will occur whenever several bursty sources simultaneously transmit at PCRs. Thus, to maintain good statistical multiplexing gain and high bandwidth utilization, a CAC algorithm (more complex than the simplest case) that can ensure a small probability of short-term overload is needed so that the QoS requirements for CLR, CDV, and CTD (as defined in GR-1110-CORE and ITU-T Rec. I.356) can still be met.

For the PVC implementation, the CAC function is a part of the provisioning process. The CAC algorithm invoked within a SONET ATM VP ring node (possibly via a management system interfacing to the ADM) will provide the connection acceptance or rejection decision to the network provider during this provisioning process. Specific detail requirements for CAC (in a UPSR or BLSR environment) are presented in Section 5.3.4.

Figure 5-5 presents the framework of an example CAC algorithm. In this example, the bandwidth requirement (BW_{Req}) for the new connection is first determined as follows:

— If it is a CBR or real-time VBR connection request, the BW_{Req} is set equal to the PCR of the request (in order to reserve the maximum bandwidth for uninterrupted transmission).

— If it is a non-real-time VBR connection request, the BW_{Req} is determined as a function of the traffic parameters (i.e., SCR and MBS) and the CLR (QoS requirement). This function estimates the amount of bandwidth needed (somewhere between PCR and SCR) so the probability of cell loss by this and other existing VBR connections (due to temporary traffic overload) is less than the CLR requirement. The derivation of this BW_{Req} function for VBR traffic depends on actual traffic generation characteristics (ATM application specific) and is beyond the scope of this GR.

— If it is a UBR connection request, no bandwidth is reserved so BW_{Req} is set to zero (thus UBR connection requests are always accepted with no service performance guarantee).

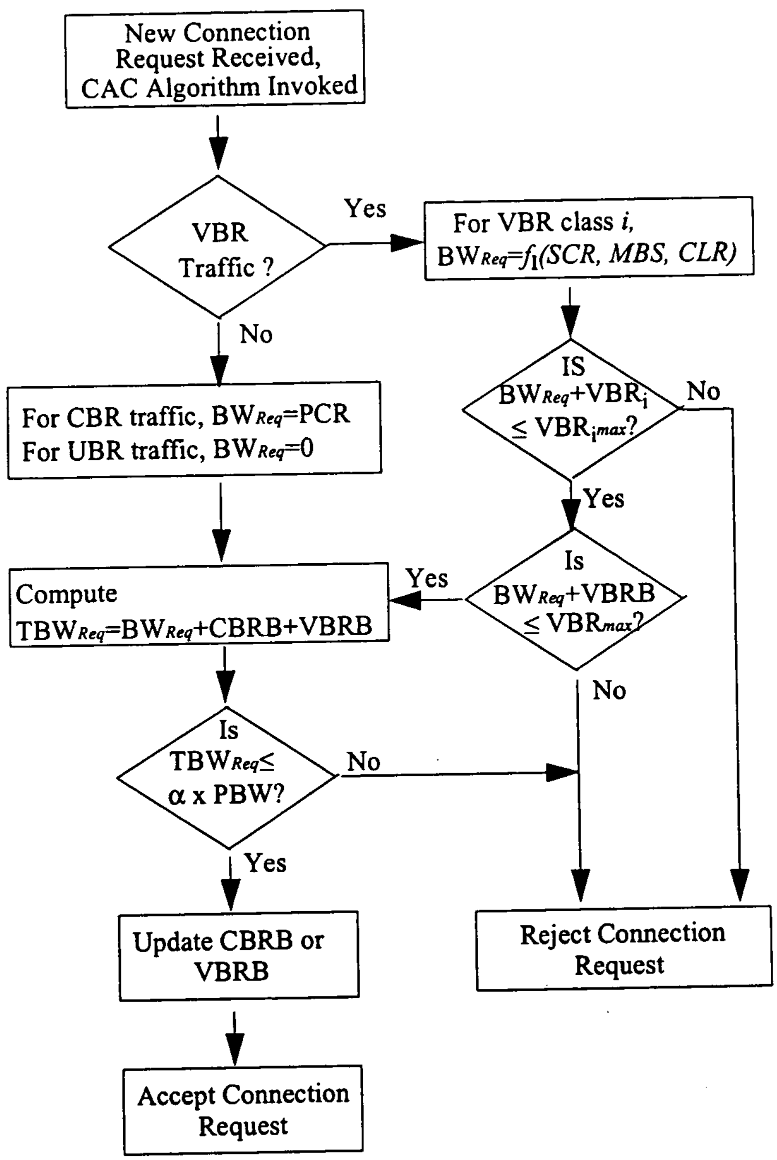


Figure 5-5. An Example CAC Algorithm

The BW_{Req} derived above is then added to existing consumed CBR bandwidth (CBRB) and consumed VBR bandwidth (VBRB) to determine if the combined total bandwidth requirement (TBW_{Req}) has exceeded a predefined bandwidth utilization threshold (i.e., calculated as a percentage (α) of the physical bandwidth (PBW) available on a STS-Nc path). The establishment of this safe operating threshold limit is based on results of SONET

ATM VP ring stress tests (i.e., by determining the maximum utilization that meets CDV requirements for CBR traffic) and is outside the scope of this GR.

In addition, VBR traffic may be subjected to additional connection acceptance rules for finer control of VBR applications mix (to further optimize overall bandwidth utilization) as follows:

— Group VBR traffic into different application classes (VBR class *i*) based on PCR ranges (e.g., class *1* for $PCR \leq 173$ cells per sec., class *2* for $173 < PCR \leq 3622$ cells per second etc.). Each class implements a class bandwidth limit (VBR_{imax}), which the existing bandwidth consumption for class *i* (VBR_i) and the new class *i* BW_{req} combined cannot exceed the defined bandwidth available to that class.

— All VBR traffic combined (new and existing) can not exceed a VBR threshold (VBR_{max}).

The above example CAC framework assumes that each SONET ATM VP ring node has some bandwidth monitoring capability (or an accounting mechanism) to determine existing bandwidth allocated for CBR and VBR traffic and will automatically reduce the values for CBRB, VBRB, and VBR_i during the tear-down phase of each connection.

5.3.1.3 Policing

The objective of the policing function is to support the QoS commitments (discussed in Section 5.3.3) for compliant CBR and VBR connections. The policing of UBR traffic can be conducted using an implicit priority scheme where UBR cells have lowest implicit processing priority; Or the policing of UBR traffic can be conducted using the explicit scheme where all UBR cells are tagged (CLP=1) upon arrival to minimize the processing of policing rules and to facilitate the selective cell discard function (this optional explicit tagging mechanism conforms to the tagging scheme for UBR.2 as described in the ATM Forum's Traffic Management Specification Version 4.0). This UBR explicit tagging action, however, does not necessarily imply a condition of non-conformance, as would be the case for other service categories. The determination as to whether conformance with a traffic contract (to be discussed in Section 5.3.2) has been violated shall be according to the rules of a policing algorithm which must be fully described by the SONET ATM VP ring node supplier. The outcome of this policing function shall be the tagging of non-conforming cells (by setting the Cell Loss Priority (CLP) bit of a cell to CLP=1).

Figure 5-6 illustrates an example policing algorithm (commonly known as the Virtual Scheduling algorithm) for the VBR cells. This algorithm, to be applied on each connection, updates a Theoretical Arrival Time (TAT), which is the expected arrival time (calculated using the PCR or other more complex formula) of the next cell. If the actual arrival time, t(K) of a cell K is not "too" early relative to the TAT, in particular if the actual arrival time is after TAT - L (where L is an early arrival tolerance limit tunable (optional) by the

network provider), then the cell is conforming (and the next TAT established by adding a time increment (I) to t(K)), otherwise the cell is non-conforming.

Optionally, a SONET ATM VP ring node supplier can also include the traffic shaping mechanism as part of the policing function (traffic shaping is done on conforming cells only). This mechanism alters the traffic characteristics of a stream of cells on a connection (while maintaining cell sequence integrity on a connection) to reduce PCR, limit burst length (for VBR traffic) and reduce one-point CDV (by suitably spacing cells in time) so better network efficiency can be achieved, or to ensure conformance at a subsequent BSS interface.

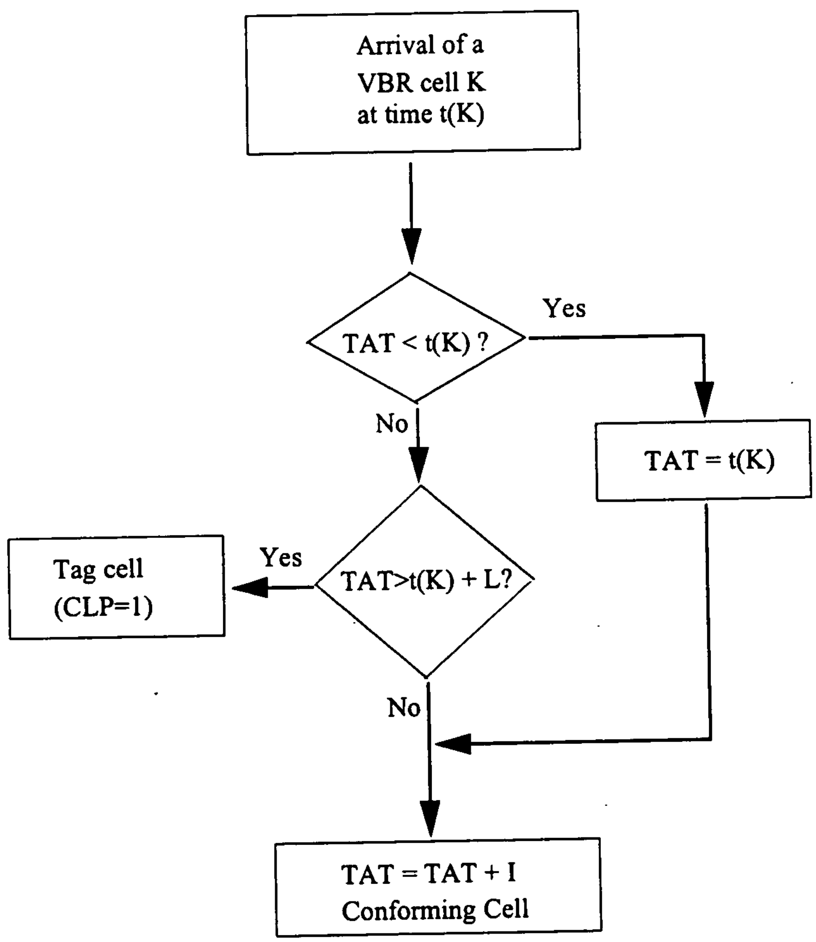


Figure 5-6. An Example Policing Algorithm for VBR Cells

5.3.1.4 Selective Cell Discard

A congested SONET ATM VP ring node will, based on the rules of its Selective Cell Discard algorithm (as described fully by the supplier and tunable by the network provider), selectively discard cells with CLP=1. This is to protect the CLP=0 flow as much as possible in meeting the QoS commitments. However, if CLP=1 cells are dropped from a connection it is expected that the CLR_0 objective for the connection, as determined by its conformance definition, will still be met.

Figure 5-7 shows an example Selective Cell Discard algorithm. The implementation of this algorithm assumes that a SONET ATM VP ring node has some measurement and monitoring capabilities in determining its traffic congestion level (e.g., based on the queue length of a STS-Nc queue, SONET ATM VP ring node processor utilization or STS-Nc path utilization etc.). The exact design and application of the selective cell discard function is vendor specific, and different rules can be used for different traffic categories (e.g., higher queue length threshold for CBR than VBR and UBR and higher queue length threshold for VBR than UBR). No matter what the design is, the ultimate goal is to support the QoS commitments negotiated for a connection (with highest priority given to the CBR traffic).

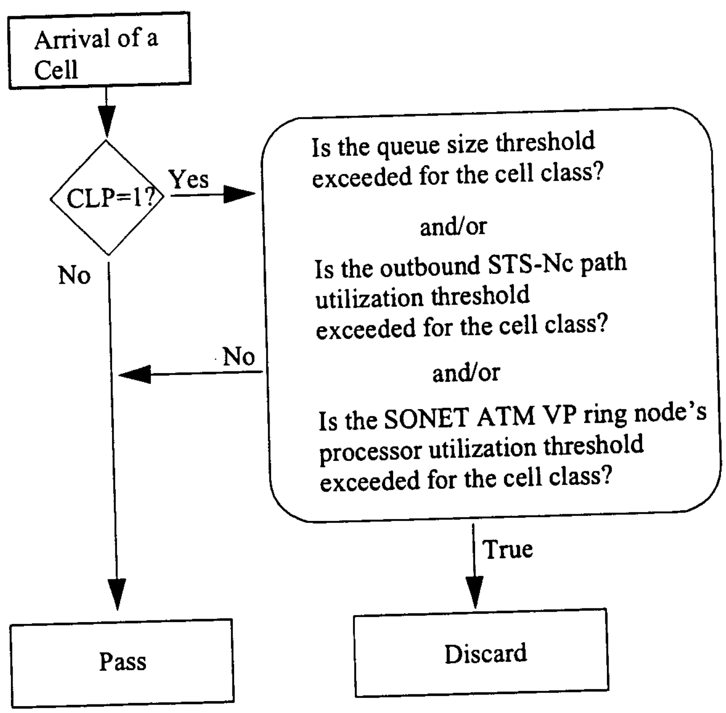


Figure 5-7. An Example Selective Cell Discard Algorithm

5.3.2 Traffic Contract

5.3.2.1 Traffic Parameters and Connection Traffic Descriptor

The connection traffic parameters describe the traffic characteristics of a VP connection (VP traffic characteristics are cumulation of VC characteristics for all VCs in a VP). The traffic parameters defined in this section include PCR, SCR and MBS. The connection traffic descriptor specifies the desired traffic characteristics of the ATM connection. The connection traffic descriptor includes the traffic parameters, the Cell Delay Variation Tolerance (CDVT), and the conformance definition (e.g., the early arrival tolerance limit (L) of the Virtual Scheduling Algorithm) that is used to unambiguously specify the conforming cells of the connection. CAC procedures will use the connection traffic descriptor to allocate resources (i.e., BW_{req}) and to derive parameter values for the operation of the policing function (i.e., the TAT and the time increment (I) of the Virtual Scheduling Algorithm).

R5-24 [48] A SONET ATM VP ring node's policing function shall be capable of enforcing any of the PCR values shown in Table 6-1 of GR-1110-CORE for any VPC.

Enforcement of any of the CDVT values shown in GR-1110-CORE for UNI or GR-1115-CORE for NNI, the SCR values shown in Table 6-3 (GR-1110-CORE) and the MBS values shown in Table 6-4 (GR-1110-CORE) by a SONET ATM VP ring node's policing function is optional.

5.3.2.2 Traffic Contract

A traffic contract specifies the negotiated characteristics of a VP connection. The traffic contract established for a connection includes the connection traffic descriptor, a set of QoS classes (described in Section 5.3.3.1) for each direction of the connection, and the definition of a compliant connection (e.g., a connection is a compliant connection when more than a certain predefined percentages of the ATM cells transported by the connection are conforming cells).

R5-25 [49] A SONET ATM VP ring node shall be capable of supporting a traffic contract (for each direction of a connection) that consists of: the traffic parameters (PCR, SCR, and MBS), the CDVT value, the connection's QoS classes, the cell conformance definition for policing and the definition of a compliant connection.

The values of the traffic contract parameters can be specified either explicitly or implicitly. A contract is explicitly specified when the values are assigned by a Network Management System (NMS) at connection subscription time. A contract is implicitly specified when the

values are assigned by the SONET ATM VP ring using default rules, which in turn, depend on the information provided by the connection end-system or subscriber.

5.3.3 QoS and Performance

This section provides ATM cell transfer performance requirements and objectives for a SONET ATM VP ring node.

5.3.3.1 SONET ATM VP Ring Performance Objectives by QoS Class

R5-26 [50] A SONET ATM VP ring node shall support the CTD, 2-pt. CDV, CLR_0, Cell Error Ratio (CER), Cell Misinsertion Rate (CMR), and the Severely-Errored Cell Block Ratio (SECBR) performance objectives for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

As specified in Clause 8.2.1 of ITU-T Rec. I.356 the CDV objective only applies to connections that have negotiated appropriately small CDV tolerances in conjunction with their PCRs. A network's CDV objective does not include the 2-point CDV resulting from network actions (such as traffic shaping) taken to reduce the amount of 1-point CDV—these actions are not considered a network-induced degradation.

O5-27 [51] It is an objective that a SONET ATM VP ring node support the CLR_{0+1} performance objective for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-28 [52] It is an objective that a SONET ATM VP ring node support the CTD, 2-pt. CDV, CLR_0, CLR_{0+1}, CER, CMR, and SECBR performance objectives for QoS Class 2 and the U Class, as defined in Table 2 of ITU-T Rec. I.356.

5.3.3.2 Multicast ATM Connection Performance Objectives

R5-29 [53] At an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node shall support the CTD, 2-pt. CDV, CLR_0, CER, CMR, and SECBR performance objectives for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-30 [54] It is an objective that at an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node support the CLR_{0+1} performance objective for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-31 [55] It is an objective that at an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node support the CTD, 2-pt. CDV, CLR_0, CLR_{0+1}, CER, CMR, and SECBR performance objectives for QoS Class 2 and the U Class, as defined in Table 2 of ITU-T Rec. I.356.

5.3.3.3 Reference Loads and Measurement

Section 8.2 of GR1110-CORE specifies the reference loads used for measuring the maximum CBR and VBR traffic loads that can be supported by a SONET ATM VP ring node (while conforming to the cell transfer performance objectives defined in Sections 5.3.3.1 and 5.3.3.2). The objective is to provide a common measurement method for specifying the capacity of different SONET ATM VP ring nodes.

R5-32 [56] A SONET ATM VP ring node supplier shall use the reference loads and methods described in Section 8.2 (of GR-1110-CORE) to measure the maximum CBR and VBR traffic loads that can be supported by a SONET ATM VP ring node (based on the cell transfer performance objectives defined in Sections 5.3.3.1 and 5.3.3.2) and shall state the measurement results in accordance with R8-1 [185] and R8-2 [186] specified in GR-1110-CORE for the STS-Nc transport facilities.

5.3.4 Traffic Management Requirements

In this subsection, the traffic management requirements utilizing CAC, Policing, and Selective Cell Discard for the ATM UPSR and BLSR environments are discussed. The term UPSR environment used here refers to the SONET ATM VP ring nodes that exist in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR. The term BLSR environment used here refers to the SONET ATM VP ring nodes that exist in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR. It is anticipated that the limited upgrade to existing SONET ATM VP ring nodes for fulfilling the following requirements will ensure achieving the increased traffic-carrying efficiency desirable for ATM networks as well as compliance with the relevant network performance objectives (which are principally the Cell Loss Ratio, Cell Transfer Delay and the Cell Delay Variation objectives associated with ATM traffic).

5.3.4.1 Traffic Management Requirements for the UPSR Environment

To protect existing ATM traffic against service quality degradation when new connection requests are made, each SONET ATM VP ring node will apply admission control to new connection requests (see example CAC algorithm in Figure 5-5).

R5-33 [57] Each SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform CAC for new connection requests of ATM traffic originating and passing through that node (on both the working and protection paths). This CAC function shall be accessible by the network provider during the PVC provisioning process, and it shall be fully described by the SONET ATM VP ring node supplier. It is also required that:

- This CAC algorithm shall provide a negative indication to the network provider whenever it is commanded to establish a PVC and this algorithm indicates that establishing such a PVC would violate the algorithm's rules.
- After providing this negative indication, and after reconfirmation by the network provider using an overriding command to establish a PVC, the CAC function shall establish that PVC.

For policing of ATM traffic in a UPSR environment, each SONET ATM VP ring node monitors and controls the inbound traffic from local (add-on) interfaces to protect network resources from malicious and unintentional misbehavior that can affect the QoS of other already established connections (see example policing algorithm in Figure 5-6).

R5-34 [58] The source SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform policing for all incoming local traffic. Cells shall be passed when they are identified by the policing function as conforming. Cells shall be tagged (CLP=1) or discarded when they are identified by the policing function as non-conforming.

In addition, each SONET ATM VP ring node in a UPSR environment may conduct traffic shaping for incoming local cell streams to achieve a desired modification of the network traffic characteristics. Figure 5-8 illustrates the filtering actions of both the policing (virtual scheduling) and traffic shaping functions in the statistical multiplexing of ATM traffic for the UPSR environment.

The selective cell discard function of a SONET ATM VP ring node determines if a tagged cell (CLP=1) shall be sent on its way to the destination or if it shall be discarded. This decision is based on congestion conditions (i.e., queue size, link utilization, and server utilization) at a SONET ATM VP ring node and the action to discard tagged cells guarantees priority processing for all conforming traffic (see example Selective Cell Discard algorithm in Figure 5-7).

CR5-35 [59] Each SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform selective cell discard for inbound and outbound traffic with a CLP=1. This

function is to be performed on both the working and the protection bandwidth.

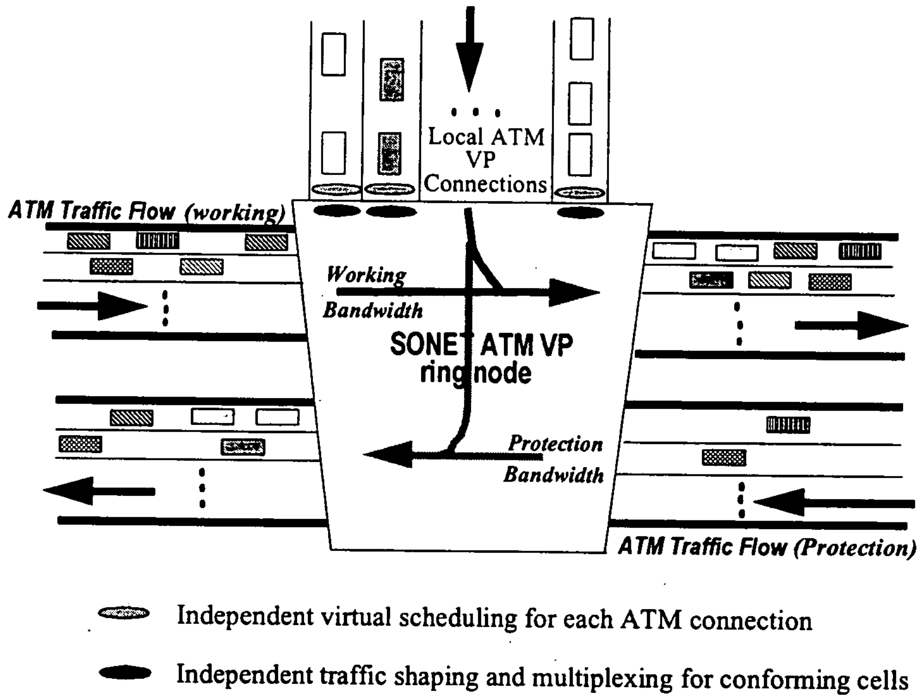


Figure 5-8. Policing and Shaping of UPSR Traffic

5.3.4.2 Traffic Management Requirements for the BLSR Environment

To protect existing ATM traffic against service quality degradation when new connection requests are made, each SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR will apply admission control to new connection requests originated both locally or elsewhere in the ring (see example CAC algorithm presented in Figure 5-5). This CAC procedure is applied only to the working bandwidth (CAC is only needed on the protection bandwidth if there is new add-on and extra traffic).

R5-36 [60] Each SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform CAC to new connection requests for ATM traffic passing that node. This CAC functionality shall be performed only on the working path (and on the

protection path if there is new add-on traffic). A formal end-to-end connection between the source and the destination is established when all CACs along the working path accept the connection request. This CAC function shall be accessible by the network provider during the PVC provisioning process, and it shall be fully described by the SONET ATM VP ring node supplier. It is also required that:

- Each CAC shall provide a negative indication to the network provider whenever it is commanded to establish a PVC and this algorithm indicates that establishing such a PVC would violate the algorithm's rules.
- After providing this negative indication, and after reconfirmation by the network provider using an overriding command to establish a PVC, the CAC function shall establish that PVC.

In applying the CAC algorithm, the computation for VBR_i, CBRB, and VBRB are calculated based on actual utilization on the working bandwidth.

For policing of ATM traffic in a BLSR environment, each SONET ATM VP ring node monitors and controls the inbound traffic from local (add-on) interfaces to protect network resources from malicious and unintentional misbehavior which can affect the QoS of other already established connections (see example policing algorithm presented in Figure 5-6).

R5-37 **[61]** The source SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform policing for inbound local traffic. Cells shall be passed when they are identified by the policing function as conforming. Cells shall be tagged (CLP=1) or discarded when they are identified by the policing function as non-conforming.

In addition, each SONET ATM VP ring node in a BLSR environment may conduct traffic shaping for inbound local cell streams to achieve a desired modification of the network traffic characteristics. Figure 5-9 illustrates the filtering actions of both the policing (virtual scheduling) and traffic shaping functions in the statistical multiplexing of ATM traffic for the BLSR environment.

The selective cell discard function of a SONET ATM VP ring node determines if a tagged cell (CLP=1) shall be sent on its way to the destination or if it shall be discarded. This decision is based on congestion conditions (i.e., queue size, link utilization and server utilization) at a SONET ATM VP ring node and the action to discard tagged cells guarantees priority processing for all conforming traffic (see example selective cell discard algorithm presented in Figure 5-7).

CR5-38 **[62]** Each SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform selective cell discard for inbound and outbound traffic with a CLP=1. This

function is to be performed on both the working and the protection bandwidth (where ATM traffic are anticipated).

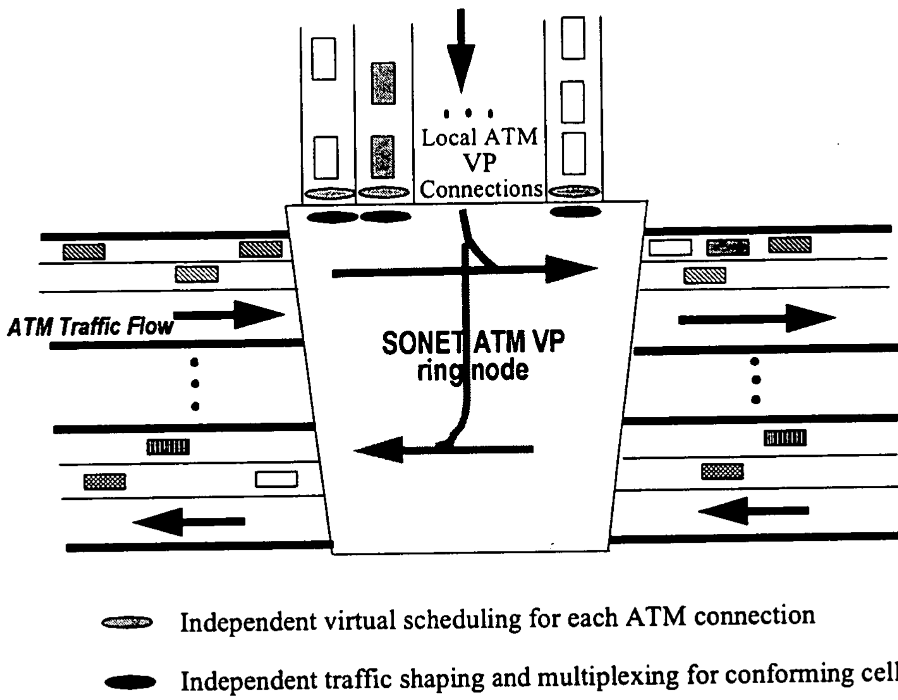


Figure 5-9. Policing and Shaping of BLSR Traffic

5.4 Network Data Collection

Network data collection is needed to support network capacity planning and engineering. Traffic data, such as congestion measurements (e.g., number of discarded cells due to congestion) and traffic load measurements (e.g., number of incoming and outgoing cells), are influenced by functional requirements and the type of network interface (e.g., UNI). Nevertheless, it is assumed that with the BSS(s) connected to the ring, most measurements made at the BSS(s) should be sufficient. Network data can be closely related to performance management information. The network usage, traffic, and performance data collected from each BSS include such items as

- Incoming cells per interface
- Outgoing cells per interface

- Incoming cells discarded on each VPL due to policing
- Intra-BSS link loads
- Cells discarded due to congestion per congestable module.

Specific requirements for the SONET ATM VP ADM are under investigation.

5.5 Operations Interfaces

In terms of managing the functionality, a Hybrid ADM operations interface(s) should align with BSS and SONET BLSR or UPSR requirements, as appropriate. The OS/NE interfaces planned are Open Systems Interconnection (OSI) using the Common Management Information Service Element (CMISE). The information modeling work is generally consistent across ATM and SONET. An initial survey found different actions in reporting Performance Monitoring (PM) data, but it is thought that they can coexist (i.e., support both sets of messages) if necessary.

R5-39 [63] The SONET ATM VP ADM shall support a generic operations interface that uses OSI/CMISE and that can support ATM messages as specified in Section 3 of GR–1248–CORE.

Regarding **R5-39**, SONET STM functions can also be supported by the same interface and it is desirable that a single set of operations interfaces to a single management system (handling both STM and ATM operations) be supported by the ring node.

O5-40 [64] It is an objective that the SONET ATM VP ADM provide a single set of operations interfaces.

A local craft access (User/System Interface) is required for SONET rings and is also needed for SONET ATM VP NEs.

R5-41 [65] The SONET ATM VP ADM shall support a User/System Interface as specified in **R1248-11** in GR–1248–CORE.

Regarding **R5-41**, it is required for local craft access to be able to retrieve information locally, as would be done by the ATM management system.

While the CMISE interface is the direction for the future in telecommunications network management, the Simple Network Management Protocol (SNMP) is a widely implemented interface in data communications equipment and small network equipment. Currently, many of the CNM systems have chosen the SNMP as their interface. One reason for its popularity is its simplicity. SNMP has a limited set of data types and structure through which information modeling is represented in simple attributes or as attributes organized in tables, in contrast to the more complex object-oriented modeling scheme in CMISE. Therefore, it is easy to implement and relatively inexpensive. Another reason for its

popularity can be attributed to its underlying communication protocol which is IP. SNMP runs over User Datagram Protocol/Internet Protocol (UDP/IP), which is provided within the TCP/IP suite of protocols. IP is the most widely used network protocol today. However, the use of SNMP for managing large NEs such as Circuit Switches (CS), Signaling Transfer Point (STP) and SONET networks is often questioned because of its limited capability in information modeling.

Many deployed SONET rings use Transaction Language 1 (TL1). Since TL1 messages have not been defined for ATM, supporting ATM operations messages in this environment may require changes for the ring node controller as well as network operations interfaces.

It is also assumed that the SONET Data Communications Channel (DCC) would not need to interwork with ATM OAM flows. This means that SONET physical layer alarms or PM need not be communicated via OAM information cells, and, conversely, ATM-related operations information derived from OAM cells need not be communicated over the SONET DCC or bit-oriented embedded operations channel. However, as suggested in O5-40, SONET alarms could be passed over an ATM management channel. Ring alarms and PM could be communicated to the BSS (or VPX) via a network operations interface (link), if the ring nodes do not directly subtend from a BSS (or VPX).

5.6 Operations Flows

Real-time operations information (e.g., failure indications, performance monitoring data) needs to flow between endpoints of a SONET physical path, an ATM VPC or VPC segment.

R5-42 [66] The SONET ATM VP ADM shall meet the requirements (in support of physical layer operations) specified in Section 4.1 of GR–1248–CORE for the appropriate drop side and ring side interfaces.

ATM layer operations flows rely on the use of OAM cells. These cells contain operations information (e.g., performance data) for an ATM connection. VPC OAM cells use dedicated VCIs (VCI=3 or 4), VCI =3 for VPC segment and VCI=4 for end-to-end VPC.

R5-43 [67] The SONET ATM VP ADM shall provide the capability to terminate, monitor, and insert segment OAM cells at segment end points, and monitor and insert OAM cells at intermediate points along a connection segment (but not terminate the flow) in support of VP service operation.

Normally, segment OAM cells all terminate at segment end points. The OAM flow is not terminated at intermediate points along a connection segment. A segment, for example, may be the VP link on the ring or the VP link access to the ring.

R5-44 [68] The SONET ATM VP ADM shall meet the requirements specified in Section 4.2 in GR–1248–CORE for VPC operations flows (F4 Flows).

Regarding **R5-44**, it is assumed that this capability is needed along a connection segment only (i.e., within the bounds of a VPC segment), and not necessarily on an end-to-end connection basis (for communicating end-to-end VPC operations information). Therefore, the VCI value 3 is used.

The need to distinguish user cells and non-user cells (OAM cell count) when performing operations tasks at the F4 (VPC) level is for further study. This relates to **R1248-250** in GR-1248-CORE.

5.7 Operations Communications

Operations communications refers to the support network that provides paths between OSs and NEs, between Mediation Devices and NEs, between NEs and NEs, and between Workstations and NEs. Generic operations communications criteria for OS/NE communications, based on the Open System Interconnection (OSI) reference model and the TMN functions, are given in GR-828-CORE.

5.7.1 Upper Layer Requirements

"Upper layers" in the OSI protocol stack refers to the three top layers (Application, Presentation, and Session layers) of the seven-layer protocol stack. Upper layer communication requirements can be divided into two classes of operations:

- Interactive class of applications
- File-oriented class of applications.

Interactive applications are time critical, spontaneous, often limited in length, and perform an atomic unit of work. Examples of such applications include Performance Monitoring, Alarm Surveillance, Testing, Network Traffic Management, Provisioning, and Network Data Collection.

R5-45 [69] The SONET ATM VP ADM shall support the Interactive Protocol Stack as specified in Section 3 of GR-828-CORE.

File-oriented applications should be used in applications such as retrieving large volume of data and less time-critical work. The operations applications include Autonomous Message Accounting, NE Memory Backup and Restoration and Software Download.

R5-46 [70] The SONET ATM VP ADM shall support the File-oriented Protocol Stack as specified in GR-828-CORE.

5.7.2 Lower Layer Requirements

"Lower layers" refers to the four bottom layers (Transport, Network, Data Link, and Physical layer) of the OSI seven-layer stack.

At least one of the following options should be supported. These options are described in GR-1248-CORE, Section 3.

R5-47 [71] The SONET ATM VP ADM shall support at least one of the four cases for the lower layers of the protocol stacks listed below.

1. TP4/CLNS lower layers
2. ATM-CLNS lower layers
3. TCP/IP over ATM
4. TCP/IP over non-ATM lower layers.

These protocol profiles use CMIP over OSI using TP4/CLNS or ATM-CLNS lower layers, or over TCP/IP (over ATM or non-ATM lower layers). These lower layers can be provided by an X.25 network, an ATM network, or other physical layer protocols.

Operations communications for SONET are covered in GR–253–CORE, Section 8. The SONET ATM VP ADM may connect to OS/NE and NE/NE paths. OS/NE communications use a *message*-oriented channel that may be provided through a dedicated physical connection or via a Data Communications Network (DCN), which may be a X.25 packet switched network, or an NE/NE path (like DCC), a LAN connection, or an ATM end-to-end VCC. NE/NE communications use a *message*-oriented channel that may be provided either through the SONET Data Communications Channel (DCC), i.e., a *message*-oriented Embedded Operations Channel (EOC) that is carried in the SONET overhead, or via a LAN if the NEs are in the same Central Office. In addition, time-critical operations flows between NEs as discussed in Section 5.6 are provided by a *bit*-oriented EOC, also in the SONET overhead (e.g., B1, B2 bytes), and an ATM OAM communications mechanism, using OAM cells.

It is assumed that generally no interworking is required between SONET layer and ATM layer operations communications (i.e., the *message*-oriented SONET EOC [i.e., the DCC] and the *bit*-oriented SONET EOC [e.g., the B1 and B2 bytes], both of which are carried in the SONET overhead, do not need to interwork with ATM OAM communications). This means that SONET physical layer alarms or performance monitoring generally need not be communicated via OAM cells, and, conversely, ATM-related operations information derived from OAM cells need not be communicated over the SONET DCC or the bit-oriented SONET EOC, but may utilize another operations interface link (although the SONET and ATM information could be mixed on one link, as stated in **O5-39**). There are, however, two exceptions. The SONET DCC can always be used as a part of an OS/NE communications path for SONET as well as ATM events. Further, the SONET ATM VP ADM always terminates the SONET path layer for signals that carry ATM, if the ATM

layer is accessed. In a SONET path that carries ATM VPCs, a SONET layer defect or defect indication requires the insertion of VP AIS into the VPCs, according to GR-1248-CORE, **R1248-64**. Specifically, a SONET STS Path AIS arriving at the SONET ATM VP ADM must be converted to VP AIS. This follows the practice that upstream failure indications are internally conveyed to the next higher layer (in this case from the SONET to the ATM layer) so that downstream failure indications can be generated.

5.8 Other Requirements

This section provides requirements that cover enabling/disabling certain SONET capabilities, operations, and maintenance of ATM PS, and the interaction (e.g., signaling, traffic management) between ATM switches (e.g., BSS) and the SONET ATM VP ADM.

5.8.1 SONET Function Enabling/Disabling

R5-48 [72] The following SONET function shall be supported (enabling/disabling) in SONET ATM VP ring nodes:

...

- SONET STS-N bandwidth (cross-connections), e.g., STS-1, STS-3c, STS-12c, shall be allocated (established) before ATM VP cross-connections can be established.

CR5-49 [73] SONET (STM) protection mechanisms and features (e.g., per STS-1) may be required to be disabled before ATM VP protection mechanisms and features can be used.

...

- This disabling of ring protection shall be done at every ring node where the STS-N terminates.

SONET and ATM layer escalation strategies may be developed that allow the use of both SONET and ATM layer protection. In such cases, both SONET and ATM layer protection mechanisms would be enabled.

5.8.2 Operations and Maintenance of ATM Protection Switching

GR-2980-CORE provides requirements on the operations and maintenance aspects of ATM PS. Fault, configuration, and performance management are covered in GR-2980-CORE.

5.8.3 Interaction with ATM Switches

R5-50 [74] The SONET ATM VP ring node shall "tunnel" signaling VCs through between CPE, edge switch, and/or ATM core switches (BSSs) in support of SVCs over switched ATM networks.

End users must tunnel their SVC requests through the hybrid network to the ATM switch. "Tunneling" signaling means that the SONET ATM VP ring ADM simply routes the cells containing signaling messages through the SONET ATM VP ADM after a signaling VC connection is made by the ATM network. This allows connections to be established on a per call (SVC) basis over the switched ATM network. GR-2842-CORE provides more discussion on how the tunneling method will operate.

In support of SVCs, the SONET ATM VP ADM and/or the ATM switch may need to be involved in the CAC process to inform the SONET ATM VP ADM of the QoS class for the connection to perform proper policing and congestion control. The CAC process uses the requested PCR, SCR, MBS, QoS class objective and CDVT in deciding to accept the connection. Communication of traffic management actions (e.g., negotiate QoS request for connection) between hybrid and/or ATM transport nodes and ATM switches is not standardized today. This is a high complexity area and is for further study. See also Section 5.3.1.

References

References are grouped below as follows: Bellcore Documents, ANSI T1 Documents, ITU-T (formerly CCITT) Documents, and ATM Forum Documents. Documents are listed in numerical order.

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American National Standards Institute (ANSI) Documents

ANSI T1.107-1995, *Telecommunications - Digital Hierarchy - Formats Specifications.*

ANSI T1.210-1993, *Operations, Administration, Maintenance and Provisioning (OAM&P) - Principles of Functions, Architectures and Protocols for Telecommunications Management Network (TMN) Interfaces.*

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NOTE:

These ANSI publications are available from:

The American National Standards Institute, Inc.
11 West 42th Street, 13th Floor
New York, NY 10036

International Telecommunications Union - Telecommunications Sector (ITU-T) [formerly Consultative Committee on International Telegraph and Telephone (CCITT)] Recommendations

ITU-T Recommendation G.774, *Synchronous Digital Hierarchy (SDH) Management Information Model.*

ITU-T Recommendation G.805, *Generic Functional Architecture of Transport Networks.*

ITU-T Recommendation I.321, *B-ISDN Protocol Reference Model and its Application.*

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ITU-T Recommendation M.3400, *TMN Management Functions.*

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These ITU-T (CCITT) publications are available from:

U.S. Department of Commerce
National Technical Information Service
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ATM Forum

ATM Forum Technical Committee on Traffic Management Specification, Version 4.0, af-tm-0056.000, April 1996.

NOTE:

ATM Forum publications are available from:

The ATM Forum
2570 West El Camino Real, Suite 304
Mountainview, CA 94040-1313
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Acronyms

AAL — ATM Adaptation Layer

ABR — Available Bit Rate

ADM — Add Drop Multiplex

ADSL — Asymmetric Digital Subscriber Line

AIS — Alarm Indication Signal

ANSI — American National Standards Institute

APS — Automatic Protection Switching

ATM — Asynchronous Transfer Mode

BCC — Bellcore Client Company

B-DCS — Broadband Digital Cross-Connect System

BER — Bit Error Rate

B-ICI — Broadband Inter-Carrier Interface

B-INNI — Broadband Intra-Network Node Interface

BITS — Building Integrated Timing Supply

B-ISDN — Broadband Integrated Services Digital Network

BLSR — Bidirectional Line-Switched Ring

BML — Business Management Layer

BSS — Broadband Switching System

BW — BandWidth

CAC — Connection Admission Control

CBR — Constant Bit Rate

CBRB — Constant Bit Rate Bandwidth

CC — Continuity Check

CCITT — International Telegraph and Telephone Consultative Committee

CDV — Cell Delay Variation

CDVT — Cell Delay Variation Tolerance

CER — Cell Error Ratio

CES — Circuit Emulation Service

CLNS — Connectionless Network Service

CLP — Cell Loss Priority

CLR — Cell Loss Ratio

CMIP — Common Management Information Protocol

CMISE — Common Management Information Service Element

CMR — Cell Misinsertion Rate

CNM — Customer Network Management

CPE — Customer Premise Equipment

CRS — Cell Relay Service

CS — Circuit Switch

DCC — Data Communications Channel

DCN — Data Communications Network

DCS — Digital Cross-Connect System

DSn — Digital Signal at Level n (n=0, 1, 3)

DSL — Digital Subscriber Line

DSLAM — Digital Subscriber Line Access Multiplexer

EFCI — Explicit Forward Congestion Indication

EM — Element Manager

EML — Element Management Layer

EOC — Embedded Operations Channel

ES — Edge Switch

FA — Framework Advisory

FRS — Frame Relay Service

GFC — Generic Flow Control

GR — Generic Requirement

HEC — Header Error Control

ILR — Issues List Report

IOF — Interoffice

IP — Internet Protocol

ITU — International Telecommunication Union

ITU-T — ITU Telecommunication

LAN — Local Area Network

LCD — Loss of Cell Delineation

LOP — Loss of Pointer

MBS — Maximum Burst Size

MFA — Management Functional Area

NE — Network Element

NEL — Network Element Layer

NML — Network Management Layer

NNI — Network Node Interface

NPC — Network Paramter Control

OAM — Operation and Maintenance

OC-N — Optical Carrier at level N (N= 1, 3, 12, 24, 48, or 192)

OS — Operations System

OSI — Open System Interconnection

PBW — Physical BandWidth

PCR — Peak Cell Rate

PHY — PHYsical

PM — Performance Management

POP — Point of Presence

PS — Protection Switching

PVC — Permanent Virtual Connection

QoS — Quality of Service

RDI — Remote Defect Indicator

RIP — Ring Interworking on Protection

SAM — Service Access Multiplexer

SAMI — SAM Interface

SCR — Sustainable Cell Rate

SECBR — Severely Errored Cell Block Ratio

SMDS — Switched Multi-megabit Data Service

SML — Service Management Layer

SNMP — Simple Network Management Protocol

SONET — Synchronous Optical Network

SPE — Synchronous Payload Envelope

SR — Special Report

STM — Synchronous Transfer Mode

STP — Signal Transfer Point

STS — Synchronous Transport Signal

STS-N — Synchronous Transport Signal at level N (N= 1, 3, 12, 24, 48, or 192)

STS-Nc — Concatenated Synchronous Transport Signal at level N (N=3, 12, or 48)

SVC — Switched Virtual Connection

TA — Technical Advisory

TAT — Theoretical Arrival Time

TBW — Total BandWidth

TCP — Transmission Control Protocol

TL1 — Transaction Language 1

TM — Terminal Multiplex

TMN — Telecommunications Management Network

TR — Technical Reference

TSA — Time Slot Assignment

TSI — Time Slot Interchange

UBR — Unspecified Bit Rate

UBRB — UBR Bandwidth

UDP — User Datagram Protocol

UNI — User-Network Interface

UPC — Usage Parameter Control

UPSR — Unidirectional Path-Switched Ring

VBR — Variable Bit Rate

VC — Virtual Channel

VCC — Virtual Channel Connection

VCI — Virtual Channel Identifier

VCL — Virtual Channel Link

VCX — Virtual Channel Cross-Connect

VP — Virtual Path

VPC — Virtual Path Connection

VPCE — Virtual Path Cross-Connection Entity

VPG — Virtual Path Group

VPI — Virtual Path Identifier

VPL — Virtual Path Link

VPM — Virtual Path Multiplex

VPX — Virtual Path Cross-Connect

VT — Virtual Tributary

W-DCS — Wideband Digital Cross-Connect System

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Requirement-Object List

R4-1 [1] All transport requirements for the SONET layer found in GR-1400-CORE, GR-1230-CORE, and GR-253-CORE must be followed for Hybrid ADMs, where applicable.

R4-2 [2] The timing mode for the SONET ATM VP ring node shall use the same timing functions (as given in GR-253-CORE) established for the STM processor (or equivalent) to synchronize all equipment interfaces.

CR4-3 [3] If the ATM functionality added to a SONET ring ADM has unrestricted ATM switching connectivity across all interfaces (VPI, VCI based connectivity) and supports SVCs (with signaling capability), then the ATM functionality shall meet the requirements of GR–1110–CORE.

CR4-4 [4] If the ATM functionality added to a SONET ring ADM is intended to provide ATM VP cross-connection functions, then the ATM functionality shall meet the ATM VPX functionality requirements of GR–2891–CORE.

CR4-5 [5] If the ATM functionality added to a SONET ring ADM is intended to serve as a SAM, then the ATM functionality shall meet the requirements of GR–2842–CORE.

R4-6 [6] If the drop side physical layer interface is between the user and the service provider (as in a service provider providing a user with VP service), then the physical layer interface shall meet the UNI physical layer interface requirements from the sections of TR–NWT–001112 specified.

... • Section 4 for the 155.520 Mb/s UNI

... • Section 5 for the 622.080 Mb/s UNI

... • Section 6 for the 51.840 Mb/s UNI

... • Section 7 for the 44.736 Mb/s UNI

... • Section 8 for the 1.544 Mb/s UNI.

R4-7 [7] For drop side non-user to service provider physical layer interfaces, the physical layer interface shall meet the NNI physical layer interface requirements from the sections of TR-NWT-001112 specified.

... • Section 9.2 for the 155.520 Mb/s NNI

... • Section 9.3 for the 622.080 Mb/s NNI

... • Section 9.4 for the 44.736 Mb/s NNI.

R4-8 [8] The PHY function for the ring side interface shall terminate the SONET STS-1, STS-3c, or STS-12c path layer as described in Section 4.3.5 of TR-NWT-001112.

R4-9 [9] ATM cell streams shall be directly mapped into STS-1, STS-3c, or STS-12c SPE payload capacity of ring side interfaces, byte aligned to the SPEs, as described in GR-253-CORE.

R4-10 [10] The PHY function for the ring side interfaces shall adapt the cell rate arriving from the ATM layer to the payload capacity of the STS-1, STS-3c, or STS-12c SPEs by inserting unassigned cells when assigned cells are not available from the ATM layer.

R4-11 [11] STS-1, STS-3c and STS-12c ring side interfaces shall meet the HEC generation, HEC check, self-synchronizing scrambler, and cell delineation requirements in Section 10 of TR-NWT-001112.

R4-12 [12] The VPM shall follow **R1113-32**, **33**, **34**, and **36** with respect to header and VPI verification.

R4-13 [13] Ring side and non-user drop side interfaces shall use the NNI cell header format.

R4-14 [14] For NNI format interfaces, the number of allocated bits of the VPI subfield shall be in accordance with **R1113-6**.

R4-15 [15] Drop side user interfaces shall use the UNI cell header format.

R4-16 [16] For UNI format interfaces, the number of allocated bits of the VPI subfield shall be in accordance with **R1113-5**.

R4-17 [17] VPIs shall be assigned bi-directionally (with bandwidth assigned independently for each direction) for the ring side interfaces (NNI) and for the drop side interfaces (UNI or NNI). A translation shall be performed on the VPIs for each terminating VPL involved.

R4-18 [18] At connection establishment, a unique VPI for each VP link (per interface) involved in the VP connection shall be associated (VPI values may or may not be different for each VP link involved), using the following VPI allocation rules:

... • the allocated bits of the VPI subfield shall be contiguous

... • the allocated bits for the VPI subfield shall be the least significant bits of the VPI subfield, beginning at bit 5 of octet 2.

R4-19 [19] The VPCE shall support the interconnection of VP links:

... • between any drop side ATM interfaces

... • between any ring side ATM interfaces

... • between any drop side and ring side ATM interfaces.

R4-20 [20] The downtime (i.e., unavailability) of any SONET STS–Nc path (between two particular nodes) carrying ATM traffic on a SONET ATM VP ring shall not be worse than the downtime of a SONET STS–Nc path carrying ATM traffic on an existing SONET Ring, as specified in Section 2 of GR-418-CORE.

R4-21 [21] The downtime of a two-way VP shall not be worse than the downtime of a two-way channel through an existing SONET Ring, as specified in Section 2 of GR-418-CORE.

R4-22 [22] A hybrid VP UPSR or ATM UVPSR shall use the ATM 1+1 VPG/ VP PS point-to-point mechanism being developed within standards.

R4-23 [23] For ring interconnection at the ATM layer, the drop-and-continue function shall be provided at the ATM layer.

R4-24 [24] For ring interconnection at the ATM layer, the selector function shall be provided at the ATM layer.

R5-1 [25] All operations requirements for the SONET layer found in GR-1400-CORE, GR-1230-CORE, and GR-253-CORE must be followed for Hybrid ADMs, where applicable.

R5-2 [26] The SONET ATM VP ADM shall meet the requirements specified in Section 5.1 of GR–1248–CORE for external update support.

R5-3 [27] The SONET ATM VP ADM shall be able to configure drop side interfaces as a Broadband Intra-Network Node Interface (B-INNI) and maintain B-INNI interface parameters as specified in **R1248-27** in GR–1248–CORE.

CR5-4 [28] If a UNI is supported, the SONET ATM VP ADM shall be able to configure drop side interfaces as a UNI and maintain UNI interface parameters as specified in **R1248-27** in GR–1248–CORE.

R5-5 [29] The SONET ATM VP ADM shall maintain information in accordance with **R1248-28** for each VPL it terminates.

R5-6 [30] The SONET ATM VP ADM shall be able to configure point-to-point and multipoint ATM VP cross-connections as specified in **R1248-32, 33, 34, 35, 36, 37, 38, 39** in GR–1248–CORE.

R5-7 [31] The SONET ATM VP ADM shall be able to identify a VPL termination point as a VPC OAM segment end point as specified in **R1248-40** and **41** in GR–1248–CORE.

R5-8 [32] The SONET ATM VP ADM shall be able to activate/deactivate ATM NE functions as specified in **R1248-42** in GR–1248–CORE.

R5-9 [33] The SONET ATM VP ADM shall provide message suppression/ duplication capabilities as specified in **R1248-43** and **44** in GR–1248–CORE.

R5-10 [34] The SONET ATM VP ADM shall provide memory query functions as specified in **R1248-45** in GR–1248–CORE.

R5-11 [35] The SONET ATM VP ADM shall provide memory backup and restoration features as specified in **R1248-46** and **50** in GR–1248–CORE, except that memory backup may be stored external to the NE.

R5-12 [36] The SONET ATM VP ADM (or adjunct) shall meet the software download requirement as specified by **R1248-54** in GR–1248–CORE.

R5-13 [37] The SONET ATM VP ADM shall meet the generic maintenance requirements for trouble detection for NEs as well as ATM NEs as specified by **R1248-56** in GR–1248–CORE.

R5-14 [38] The SONET ATM VP ADM shall meet the ATM VP layer defect detection requirements as specified in **R1248-63, 64,** and **70** in GR–1248–CORE.

R5-15 [39] The SONET ATM VP ADM shall meet the failure timing and failure notification requirements as specified in **R1248-72, 73, 74, 75,** and **76** in GR–1248–CORE.

R5-16 [40] The SONET ATM VP ADM shall meet the requirements for physical layer defect and failure detection as specified in **R1248-57, 58, 59, 60,** and **62** in GR–1248–CORE.

O5-17 [41] The SONET ATM VP ADM should meet generic maintenance requirements for trouble isolation and provide internal supplier-specific diagnostics as specified by requirements **R1248-79, 80, 81, 82,** and **O1248-83** in GR–1248–CORE.

CR5-18 [42] The SONET ATM VP ADM may be required to provide OAM cell loopback capability support on VP (F4) Flows at segment end points as specified in **R1248-87, 89,** and **92** in GR–1248–CORE.

CR5-19 [43] The SONET ATM VP ADM may be required to provide the CC capability on VPCs and segments as specified in Section 6.1.2.4 in GR–1248–CORE.

R5-20 [44] The SONET ATM VP ADM shall meet the PM requirements specified in Section 7.1.1.1 of GR–1248–CORE for the appropriate DSn ATM drop side interfaces to the ring.

R5-21 [45] The SONET ATM VP ADM shall meet the requirements for monitoring the ATM cell header processing as specified in **R1248-97, 98,** and **99** in GR–1248–CORE.

O5-22 [46] It is an objective for the SONET ATM VP ADM to meet the objective in GR-1248-CORE, **O1248-102,** for protocol monitoring of OAM cells.

CR5-23 [47] If a SONET ATM VP ADM needs to support point-to-point VP OAM PM cell flows, then the requirements in GR-1248-CORE Sections 4.2, 7.1.3, and 8 shall apply addressing OAM PM cell formatting, generation, and activation/deactivation that are needed to monitor the following performance parameters:

... • number of 0+1 user cells lost (i.e., background cell lost)

... • number of 0 cells lost (i.e., cells lost between the source ATM NE and the destination ATM NE)

... • total number of misinserted cells (i.e., cells misrouted to the destination ATM NE)

... • errored cell events (i.e., cells delivered to the destination ATM NE with bit error(s) in the payload).

R5-24 [48] A SONET ATM VP ring node's policing function shall be capable of enforcing any of the PCR values shown in Table 6-1 of GR-1110-CORE for any VPC.

R5-25 [49] A SONET ATM VP ring node shall be capable of supporting a traffic contract (for each direction of a connection) that consists of: the traffic parameters (PCR, SCR, and MBS), the CDVT value, the connection's QoS classes, the cell conformance definition for policing and the definition of a compliant connection.

R5-26 [50] A SONET ATM VP ring node shall support the CTD, 2-pt. CDV, CLR_0, Cell Error Ratio (CER), Cell Misinsertion Rate (CMR), and the Severely-Errored Cell Block Ratio (SECBR) performance objectives for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-27 [51] It is an objective that a SONET ATM VP ring node support the CLR_{0+1} performance objective for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-28 [52] It is an objective that a SONET ATM VP ring node support the CTD, 2-pt. CDV, CLR_0, CLR_{0+1}, CER, CMR, and SECBR performance objectives for QoS Class 2 and the U Class, as defined in Table 2 of ITU-T Rec. I.356.

R5-29 [53] At an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node shall support the CTD, 2-pt. CDV, CLR_0, CER, CMR, and SECBR performance objectives for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-30 [54] It is an objective that at an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node support the CLR_{0+1} performance objective for QoS Classes 1 and 3, as defined in Table 2 of ITU-T Rec. I.356.

O5-31 [55] It is an objective that at an add/drop point for a root-to-leaf pair component of an ATM multicast connection a SONET ATM VP ring node support the CTD, 2-pt. CDV, CLR_0, CLR_{0+1}, CER, CMR, and SECBR performance objectives for QoS Class 2 and the U Class, as defined in Table 2 of ITU-T Rec. I.356.

R5-32 [56] A SONET ATM VP ring node supplier shall use the reference loads and methods described in Section 8.2 (of GR-1110-CORE) to measure the maximum CBR and VBR traffic loads that can be supported by a SONET ATM VP ring node (based on the cell transfer performance objectives defined in Sections 5.3.3.1 and 5.3.3.2) and shall state the measurement results in accordance with R8-1 [185] and R8-2 [186] specified in GR-1110-CORE for the STS-Nc transport facilities.

R5-33 [57] Each SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform CAC for new connection requests of ATM traffic originating and passing through that node (on both the working and protection paths). This CAC function shall be accessible by the network provider during the PVC

provisioning process, and it shall be fully described by the SONET ATM VP ring node supplier. It is also required that:

... • a. This CAC algorithm shall provide a negative indication to the network provider whenever it is commanded to establish a PVC and this algorithm indicates that establishing such a PVC would violate the algorithm's rules.

... • b. After providing this negative indication, and after reconfirmation by the network provider using an overriding command to establish a PVC, the CAC function shall establish that PVC.

R5-34 [58] The source SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform policing for all incoming local traffic. Cells shall be passed when they are identified by the policing function as conforming. Cells shall be tagged (CLP=1) or discarded when they are identified by the policing function as non-conforming.

CR5-35 [59] Each SONET ATM VP ring node in a ATM UVPSR Ring or Hybrid VP UPSR or Hybrid UPSR shall provide the capability to perform selective cell discard for inbound and outbound traffic with a CLP=1. This function is to be performed on both the working and the protection bandwidth.

R5-36 [60] Each SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform CAC to new connection requests for ATM traffic passing that node. This CAC functionality shall be performed only on the working path (and on the protection path if there is new add-on traffic). A formal end-to-end connection between the source and the destination is established when all CACs along the working path accept the connection request. This CAC function shall be accessible by the network provider during the PVC provisioning process, and it shall be fully described by the SONET ATM VP ring node supplier. It is also required that:

... • a. Each CAC shall provide a negative indication to the network provider whenever it is commanded to establish a PVC and this algorithm indicates that establishing such a PVC would violate the algorithm's rules.

...

- b. After providing this negative indication, and after reconfirmation by the network provider using an overriding command to establish a PVC, the CAC function shall establish that PVC.

R5-37 **[61]** The source SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform policing for inbound local traffic. Cells shall be passed when they are identified by the policing function as conforming. Cells shall be tagged (CLP=1) or discarded when they are identified by the policing function as non-conforming.

CR5-38 **[62]** Each SONET ATM VP ring node in a ATM BVPSR Ring or Hybrid VP BLSR or Hybrid BLSR shall provide the capability to perform selective cell discard for inbound and outbound traffic with a CLP=1. This function is to be performed on both the working and the protection bandwidth (where ATM traffic are anticipated).

R5-39 **[63]** The SONET ATM VP ADM shall support a generic operations interface that uses OSI/CMISE and that can support ATM messages as specified in Section 3 of GR–1248–CORE.

O5-40 **[64]** It is an objective that the SONET ATM VP ADM provide a single set of operations interfaces.

R5-41 **[65]** The SONET ATM VP ADM shall support a User/System Interface as specified in **R1248-11** in GR–1248–CORE.

R5-42 **[66]** The SONET ATM VP ADM shall meet the requirements (in support of physical layer operations) specified in Section 4.1 of GR–1248–CORE for the appropriate drop side and ring side interfaces.

R5-43 **[67]** The SONET ATM VP ADM shall provide the capability to terminate, monitor, and insert segment OAM cells at segment end points, and monitor

and insert OAM cells at intermediate points along a connection segment (but not terminate the flow) in support of VP service operation.

R5-44 [68] The SONET ATM VP ADM shall meet the requirements specified in Section 4.2 in GR–1248–CORE for VPC operations flows (F4 Flows).

R5-45 [69] The SONET ATM VP ADM shall support the Interactive Protocol Stack as specified in Section 3 of GR–828–CORE.

R5-46 [70] The SONET ATM VP ADM shall support the File-oriented Protocol Stack as specified in GR–828–CORE.

R5-47 [71] The SONET ATM VP ADM shall support at least one of the four cases for the lower layers of the protocol stacks listed below.

R5-48 [72] The following SONET function shall be supported (enabling/ disabling) in SONET ATM VP ring nodes:

...

- SONET STS-N bandwidth (cross-connections), e.g., STS-1, STS-3c, STS-12c, shall be allocated (established) before ATM VP cross-connections can be established.

CR5-49 [73] SONET (STM) protection mechanisms and features (e.g., per STS-1) may be required to be disabled before ATM VP protection mechanisms and features can be used.

...

- This disabling of ring protection shall be done at every ring node where the STS-N terminates.

R5-50 [74] The SONET ATM VP ring node shall "tunnel" signaling VCs through between CPE, edge switch, and/or ATM core switches (BSSs) in support of SVCs over switched ATM networks.

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